AUDIO PROGRAM DISTRIBUTION IN CABLE TELEVISION SYSTEMS

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ABSTRACT

Conventional stereo-FM audio transmission on cable is analyzed as "mediocre". Digital transmission to a new generation of digital audio receivers is recommended. Additional bandwidth is required but is judged worthwhile.

AUDIO PROGRAM SERVICES ON CABLE

Present audio program services on cable systems consist mainly of:

- FM radio stations (stereo) received off-air and redistributed in the cable system in the 88 - 108 MHz band, and

- FM radio stereo services (88 - 108 MHz band) which are generated at the head-end as "simulcasts" of the audio program of certain TV program services. These "simulcasts" might be intended as substitutes for the BTS stereo audio originally provided with the television program or might be "high fi stereo" augmentation of television programs that otherwise have "mono audio" only.

- New "pay cable audio" services which are generated at the head-end as a "premium" audio service offering commercial-free music on a subscription basis. These "pay cable audio" services should for the time being be considered "experimental" since their commercial success is not yet established nor is there any concensus yet on the transmission technology.

Most of these services use the conventional FM-stereo signal format so as to be receivable by subscribers on ubiquitous FM-stereo radio receivers. "Pay cable audio" services use a variety of transmission techniques. Some use conventional FM-stereo format but transmit in a band other than the usual 88 108 MHz band. This system counts on the use of "non-standard" spectrum as a "service security" technique. Some "pay cable audio" systems use other analog transmission technologies such as use of discrete L and R carriers.

PROBLEMS OF CONVENTIONAL FM-STEREO TRANSMISSION IN CABLE SYSTEMS

Cable audio services which use conventional FM-stereo transmission, as presently distributed on cable systems, provide mediocre service as measured by "professional" or "audiophile" standards, principally because of,

- inadequate carrier levels in the cable distribution system, and

- inadequate head-end processing and modulation equipment.

The low carrier levels make it impossible to provide adequate demodulated audio S/N (stereo) from cable stereo-FM transmissions. Inadequate head-end equipment compromises stereo separation and audio distortion characteristics.

FM-STEREO CARRIER LEVELS IN CABLE SYSTEMS

Conventional FM-stereo transmission provides stereo by means of an L-R subcarrier. Since the L-R subcarrier gets only a small proportion of the available FM deviation it effectively has only a small proportion of the available "signal power". In marginal C/N situations the stereo L-R subcarrier suffers significant quality degradation. The demodulated L-R baseband has poor S/N. When "matrixed" with the main channel L+R baseband to produce separate L and R basebands the noisy L-R baseband introduces excessive noise. This is a well known effect in FM-stereo radio broadcasting. The effective reach of an FM radio broadcast station is substantially reduced when it broadcasts in stereo, compared to "mono". Stereo transmission suffers a penalty of approximately 20 dB compared to "mono" FM radio transmission. Cable transmission of FM-stereo suffers from exactly the same effects.

EFFECT OF CABLE SYSTEM NOISE ON FM-STEREO TRANSMISSION (1,2,)

The carrier to noise ratio for FM signals in a CATV system can be calculated as follows:

$$C/N_{(FM)} = C/N_{(TV)} + 10 \log \frac{BW\ (TV)}{BW\ (FM)} - [L_{(TV)} - L_{(FM)}]$$

BW (TV) = noise bandwidth of TV signal
BW (FM) = noise bandwidth of FM signal
C/N (FM) = carrier to noise ratio for FM signals in cable system
C/N (TV) = carrier to noise ratio for TV signals in cable system
L (TV) = carrier level (dBmV) of TV visual carrier
L (FM) = carrier level (dBmV) of FM carrier
S/N (FM) = signal to noise ratio at output of FM receiver

A cable system operating to minimum FCC specification could have a visual carrier to noise ratio as low as 36 dB in a 4 MHz bandwidth. It is the usual American cable system practice to transmit FM-stereo services 15 dB below TV visual carrier levels. If we consider an FM radio receiver to have a 180 KHz bandwidth the C/N for the FM-stereo signal would be

$$C/N_{(FM)} = 36 + 10 \log 4000/180 - 15 = 34.5 \text{ dB}$$

Is this an adequate C/N for satisfactory FM-stereo transmission? No! Generally accepted relation- ships (for 180 KHz noise bandwidth) between FM C/N and demodulated baseband S/N

$$S/N_{(FM)} = C/N_{(FM)} + 15 \text{ dB}$$

indicate that this 34.5 dB C/N would provide only 49.5 dB baseband audio S/N. 67 dB S/N would be a desirable objective for "imperceptible" noise. A more typical cable system would have 5 - 7 dB better noise situation, but more typical "hi-fi" FM receivers would have a wider IF and noise bandwidth. Typical FM receiver operation on cable might also be degraded by 1 or 2 dB because of relatively low input signal levels. The calculation for a "43 dB C/N" cable system and a 240 KHz noise bandwidth receiver would be

$$C/N_{(FM)} = 43 + 12.2 - 15 = 40.2 \text{ dB}.$$

This would produce a baseband S/N of only 55 dB, still 12 dB short of "imperceptible" noise and 3 dB short of "just perceptible" noise.

The IEC standards, prevalent in Europe, call for $C/N_{(FM)}$ of 51 dB (in 200 KHz bandwidth) for FM-stereo services in cable. Cable systems in Europe do operate with high (compared to U.S. practice) FM-stereo carrier levels, typically -3 dB to -6 dB relative to TV visual carrier. They can do so because they carry relatively few FM-stereo and TV channels and they have designed their systems for this FM-stereo performance objective from the very beginning.

HEAD-END SIGNAL PROCESSORS AND STEREO MODULATORS

Most cable systems process off-air FM-stereo services by heterodyne techniques. Virtually all American systems use the popular CATEL FM radio heterodyne signal processor. This is virtually the only FM radio signal processor available in the American market and has been sold unchanged for more than ten years. Cable systems cannot complain about the price but fussy users might make some adverse comments on specification and performance. The CATEL unit provides good (but not superlative) signal processing at a very reasonable price. It does not, however, meet "professional" standards for "heterodyne repeaters". The various European national broadcast authorities are large scale users of heterodyne FM radio signal processors in FM radio rebroadcast facilities (FM radio "translators"). Their specifications for "FM translators" are much more rigorous than the spec' met by the low cost CATEL processor, particularly in the area of IF group delay distortion and AM/PM conversion. IF group delay distortion affects stereo separation. The CATEL IF is not as good as that found in current "top of the line" FM-stereo radio receivers. I do not blame CATEL. They respond to the market and the American cable system market has not demanded or expressed a willingness to pay more for higher quality FM-stereo signal processors.

The rest of the audio signal processing equipment (subcarrier demodulators, stereo generators, etc.) found in the typical cable system head-end has similar characteristics - "good" but not "superlative" specification at low cost, in response to the manufacturers' peception of the current head-end equipment market. This equipment would not be used by fussy "professional" buyers of FM-stereo broadcast equipment.

The attitude of cable system operators is perhaps understandable. FM-stereo broadcasters who's entire revenue is bound up in the transmission of a single service will lavish much care and attention on the selection and maintenance of their origination equipment. A cable system operator who operates perhaps forty such services, and who can perceive very little direct revenue coming from them, will spend the minimum amount which provides acceptable service.

REMEDIES

INCREASED CARRIER LEVELS

If low C/N is the problem in cable system transmission of FM-stereo services, why not raise the carrier levels? Cable systems in Europe usually carry FM-stereo services at 3 dB below TV visual carrier levels to provide first class service.

American systems cannot raise FM-stereo carrier levels because the high carrier levels required would overload the system. The total power of forty FM-stereo carriers at identical levels is

$$10 \text{ Log } 40 = 16 \text{ dB}$$

greater than the power of a single carrier. Put another way, at -3 dB relative to TV visual carrier it requires only two FM-stereo carriers to equal the peak power of a single TV visual carrier. Forty such carriers would be equivalent to twenty TV carriers. Raising the FM-stereo carrier level, in a system carrying forty such FM-stereo services, to -3dB relative to TV visual, would be equivalent to adding twenty TV channels to the system loading! Our present system designs just won't stand that much additional loading. Alternately, if the system is to be designed to accept that much additional loading, system operators would prefer that the loading be TV channels from which significant revenues can be more clearly and certainly expected.

Increased FM-stereo carrier level is not a practical solution in American cable systems.

CHANGES IN MODULATION TECHNIQUE

INCREASED DEVIATION

The FM deviation could be increased from the present 75 KHz standard. This would trade occupied bandwidth for noise performance. The increased deviation could be provided at the headend by a multiplication and heterodyning process, but additional spectrum would have to be found and new FM-stereo receivers for the new IF and deviation developed and provided to subscribers.

COMPANDED L-R BASEBAND

"If we knew then what we know now" we would have used companding of the L-R baseband in conventional FM-stereo radio broadcasting, as used in the new BTS stereo audio standard for television audio broadcasting. Introducing it now would mean new FM-stereo receivers for subscribers and complex demodulation and remodulation equipment requirements for cable system headends.

DISCRETE L/R TRANSMISSION USING FM

Handling of L and R basebands as discrete channels would improve transmission and stereo separation but would also require new receivers for subscribers as well as increased bandwidth in the cable system.

DISCRETE L/R BASEBAND TRANSMISSION USING AM

We can calculate the performance of an AM transmission technique using a 15 KHz noise bandwidth in a cable system with a 36 dB $CN_{(FM)}$. The 15 KHz noise bandwidth has

$$10 \log 4000/15 = 24.3 \text{ dB}$$

less noise than the TV visual carrier. At -15 dB relative to TV visual the audio service AM carrier would have a

$$C/N = 36 + 24.3 - 15 = 45.3 \text{ dB.}$$

We would save a lot of bandwidth since a stereo channel would require only about 60 KHz but we would need very high carrier levels to achieve 70 dB C/N. Loading effects would be intolerable unless suppressed carrier transmission was used. Special receivers would be required.

DIGITAL MODULATION

If the cable system has to change modulation technique, allocate additional bandwidth and use special receivers in order to provide superlative audio services why not go "all the way" - to digital! It is true that "superlative" service can be achieved by analog transmission. Several such techniques have been proposed and demonstrated for the new "pay cable audio" services. Superlative service is also achievable by digital transmission. The advantages of digital audio techniques have been demonstrated by the nearly universal acceptance of digital audio for master recording in professional sound studios and the rapid growth of digital "compact discs" (CD's) in the consumer market. Why fool around with analog when digital is:

Unquestioned performance specifications - digital audio systems meet the highest professional standards for audio system performance.

Low cost - the prices quoted by these companies for head-end equipment and for subscriber receivers are very reasonable for the facility provided - highest quality digital audio performance, comprehensive "addressability", secure encyphering. Prices would be even lower if a technical standard was agreed on before introduction of the service.

The only disadvantage that I would acknowledge is the increased bandwidth requirement. A typical "ultra-high-fidelity" stereo digital service (Panasonic) uses a 1 MHz transmission channel. This compares with a 400 MHz transmission channel (typical spacing) for conventional FM-stereo transmission in cable. The effective "occupied bandwidth" for the highest quality digital transmission mode is about twice that of conventional analog FM-stereo transmission. This is not a bad trade-off, particularly since digital transmission could occupy spectrum that is otherwise problematical for TV transmission (e.g. the entire 88 - 136 MHz band, 48 MHz in total). This spectrum should be available in most cable systems. Digital audio carrier levels would be low - below the threshold of FCC rule 76.610. Digital audio service should be a very acceptable replacement for the conventional FM-stereo service presently offered by cable systems in the 88 - 108 MHz band - and would not cause system loading problems. Small cable systems with a large number of FM-stereo subscribers might not wish to make the change if their subscribers are happy with the present quality of service. My experience in large urban systems is that subscribers are generally not very happy with the quality of service presently provided.

The Japanese companies who are proposing digital audio technologies for cable system use are gradually providing some of the technical details. They typically provide both a "super high fidelity" mode using 16 bit linear encoding and a "high fidelity" mode using 8 bit "digitally companded" encoding. Discrete L and R transmission is provided. I would personally prefer a standard which is directly compatible with the digital chips in the CD players presently being marketed. Ideally the cable digital audio receiver should be integrated with the CD player to provide a "radio receiver" complement to the CD player. The digital cable audio receiver could share the D/A converter(s) and filters in the CD player.

I see no reason why cable digital audio receivers should not be owned by the subscriber. The encyphering and addressing techniques should be sufficiently secure to allow subscriber ownership. An agreement on standards among interested manufacturers would keep equipment costs down and create a competitive market which would benefit cable subscribers. Cable systems would also benefit by being relieved of the burden of buying and maintaining this particular piece of subscriber terminal equipment.

AN OPERATING SCENARIO FOR DIGITAL AUDIO SERVICES

Initially cable systems would have to provide high quality receiving and demodulation equipment at the head-end to derive quality L and R baseband for remodulation to digital format. Eventually audio service providers will see the wisdom of transmitting in digital format from the program provider's main studios. FM-stereo radio broadcasters will continue to broadcast in conventional analog format, but there is no reason why there should not eventually be a digital radio broadcast service as an improvement over FM in the same way that FM radio broadcasting was introduced as an improvement over AM. Digital transcoding equipment will no doubt be available for directly translating digital audio received at the head-end from the received digital format to the digital format used by the cable system for distribution to subscribers. Again, an industry-wide agreement on standards for transmission would be very desirable.

(1) CABLE TELEVISION SYSTEM CAPABILITY FOR TRANSMISSION OF FM BROADCASTING SIGNALS - Paul K. Wong - Cable TV Standards & Practices - Department of Communications, Government of Canada - 1978.

(2) CAFM ADAPTABILITY OF FM RECEIVERS - Tsuneo Takezaki, Michio Okamoto, Junji Suzuki - Wireless Research Laboratory - 1975 - translated from Japanese by Cable TV Standards & Practices - Department of Communications, Government of Canada.