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Designing for Pay

By Patrick Loughboro

There are two business options open to the for-profit, TV broadcaster: advertiser-supported "commercial" television (CTV) or user-fee-based "subscription" television (STV). There are, of course, combinations of the above, where commercials appear on STV programs, but public resistance to the intrusion of advertising into a contract for uninterrupted entertainment has been high, and most popular business plans have relied on one but not both of these sources of revenue. Educational, instructional, ecclesiastical and public TV broadcasting systems may generate "excess revenue" but all of these are classified as non-profit so will not be discussed here.

It is interesting to note that the very first proponents of TV broadcasting contemplated the adoption of a subscription service. Unfortunately, origination, transmission and reception technologies were difficult and were evolving between the late 1920s and 1953 (when the NTSC color compatible system was conceived in the U.S.) and 1967 (when PAL found regular service in England). It was difficult enough to faithfully process video; it would not have been economically feasible to implement a reliable encryption system in the first half of television's nearly 70 years of evolution.

With the extensive growth of cable, satellite, UHF, MMDS and other services to paying subscribers there are encode-encode systems that are now reliable, secure and low in cost.

Decision to proceed

For the commercial operator to succeed, the origination (video tape, film, satellite, etc.) and transmission facilities should be adequate to provide clear, noise-free pictures and sound to the viewer. In CTV the viewer is usually expected to decide on reception equipment and installation details. The broadcaster concentrates on programming, selling commercial time and maintaining a satisfactory technical plant, increased viewership follows quality of information and entertainment, and revenues flow accordingly.

For the STV operator to succeed, demands on the technical facilities increase several-fold. Program quality remains important although content may change depending upon tastes of the community and competitive offerings in the area. Administration now concentrates on billings and collections; engineering must not only maintain peak performance in the origination and transmission facilities, but must now ensure that equipment and installation details at the subscriber meet minimum standards. Increased viewership now depends on continuing station involvement with the technical performance of subscriber equipment.

We will assume that market research, business analyses and related factors have resulted in a decision to proceed with a subscription TV service.

System demands

The heart of any broadcast operation is the TV transmitter. Within itself a transmitter is a system, embracing most of the challenges of modern physics and engineering, including microelectronics, mechanics, thermodynamics, low and high voltages (sometimes involving relativistic particle velocities), vacuum technology, metallurgy and magnetics.

Whatever band of service is chosen from VHF to microwave, the broadcaster should select the most linear transmitter design available. Low cost designs using class AB amplifiers may be satisfactory in CTV service but will introduce distortion products during encryption that may render STV decoding impossible. As stated previously, under "Decision to proceed" the technical demands on the transmitter increase significantly for STV service, and compatibility with the encoding system is essential.

Numerous and detailed publications deal extensively with options, technical and cost trade-offs, and equipment evaluation criteria for the many elements of STV broadcast operations. In this article we will focus on the single-channel transmitter in the multichannel multipoint distribution service (MMDS).

Transmitter evaluation criteria

Currently there are four full-line manufacturers of all solid state, US FCC-type accepted, MMDS transmitters. Each company has adopted its own design philosophy to meet market demands; and, as you might suspect, there are very significant differences in the products offered.

Whether one feature dominates your thinking or you establish an overall figure of merit, an informed selection criteria is possible. The technology is not difficult; you can and should ask the tough questions and expect clear and understandable answers when trying to decide which product best suits your needs. Following are some of the more critical elements that should be included in the evaluation process:

Amplifiers. The market and license demand a certain transmitter power output. The manufacturer simply must choose a design approach among limited variables to meet this demand. Should the manufacturer:

1) Use GaAs MESFET or bipolar devices in all RF amplifier stages? If lower performance bipolars are used then the overall design will be higher in cost and greater in complexity for the same system performance.

2) Operate final amplifiers at heir maximum rating? To prevent distortion and allow margin for change over life of the equipment it is preferable to operate final amplifiers below their maximum ratings.

3) Operate driver amplifiers in such linear regions so as not to contribute distortion to the final amplifier? Doing so ensures excellent long-term performance without adjustment.

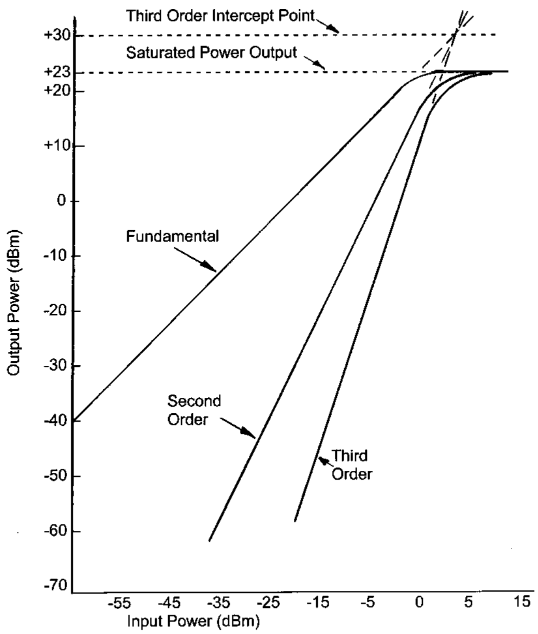
4) Include state-of -the-art gain stages at logical breaks in power output? Performance without distortion is achieved at low cost if the design philosophy is so directed.

5) Use separate amplification of visual and arual carriers to further reduce distortion such as third-order intermodulation (IM3), or should the manufacturer adopt combined amplification to reduce cost (e.g. visual and aural carriers combined at IF and amplified in common RF stages)?

6) Use low-cost coaxial diplexing or higher cost waveguide diplexing of visual and aural amplifier chains?

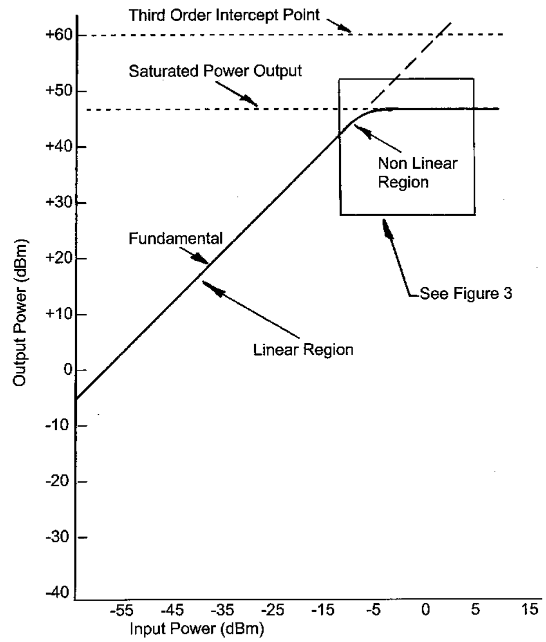
Ultra-linear class A amplifier operation will ensure long term, trouble-free, excellent picture and sound quality. Such a robust, conservative design is more forgiving of other system elements that may be marginal in performance, and for STV operations the encrypted signal will be transmitted as intended. No new distortions will be added to the encrypted signal that might confuse the home decoder and prevent re-creation of the original signal.

Two manufacturers compromise linearity for some cost reduction. For example the ultralinear design involves one amplifier driving two, driving four amplifiers to achieve power output without distortion. The compromise design involves one driving four amplifiers. Elimination of the second stage may reduce cost but the driver and final stages are now pressed to their maximum ratings to achieve power. There is no headroom and no margin for change over life between adjustments. Pictorially, amplifier characteristics follow classical curves as in Figure 1.



Gain = 25dB
Power Output = +20dBm @ 1dB Gain Compression
Third Order Intercept Point = +30dBm

FIGURE 1: THEORETICAL AMPLIFIER



LSI25ST Visual Gain = 60dB
Power Output = +45dBm (32 watts) @ 1dB Gain Compression
Third Order Intercept Point = +60dBm

FIGURE 2: ACTUAL ULTRA LINEAR TRANSMITTER

A fourth manufacturer incorporates extremely complex arrays of precorrection or predistortion circuits in the modulator to reverse compensate for known degradation that is expected in the low-cost, nonlinear, video RF amplifiers. Envelope delay precorrection, sync stretch, differential phase and differential gain compensation, etc. should not be necessary in MMDS equipment, so offers of these "features" are probably an indication of a poor or lowest-possible-cost amplifier design. Since precorrection adjustments interrelate, it is difficult to maintain concert in overall performance at the factory; and, it is very difficult in the field.

The ultralinear design operates final amplifiers at greater than 1 dB below P(1 dB) (see Figures 2 and 3). Prior stages of amplification include increasing headroom that follows a conservative design curve (see Figure 4). The compromise design operates final amplifiers at P(1 dB) or above (see Figure 3) and allows little headroom in previous stages. The low-cost design operates near saturation with no headroom in previous stages (remember, anticipated degradation is to be precorrected by reverse compensation in the modulator).

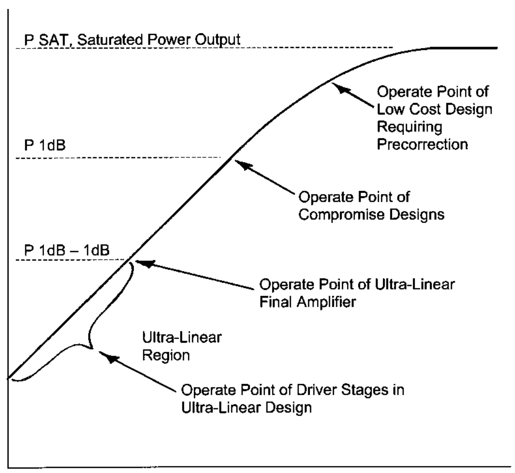


FIGURE 3: OPERATE POINT OPTIONS

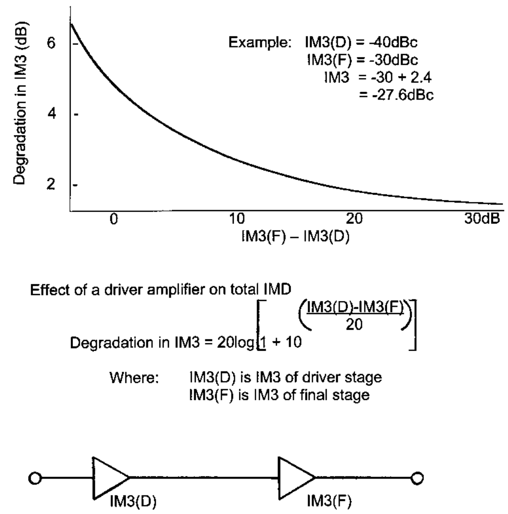


FIGURE 4: Effect of Headroom in Driver Stages Using Ultra-Linear Design Amplifiers

A few of the more important benefits of the ultralinear design are:

- No introduction of waveform distortion, amplifiers are transparent to the video signal.
- All amplifiers can be modular and broadbanded. Field replacements are quick and easy with no tedious tuning requirements or need for critical adjustments. One spare module package can back up 31 transmitters, with no need for custom components.
- Simple low-cost modulators and upconverters are usable. No requirements for complex precorrection circuits.
- With simple modulators and ultralinear amplifiers any known encode-decode system is possible. Introduction of slight distortions in compromise or low-cost designs render decoding at the home impossible.

Upconverters.

1) Local oscillators should be frequency synthesized for agile tuning and should exhibit low phase noise. Phaselocked oscillators should be able to be locked to a master clock for adjacent channel operation or other high frequency stability requirement. Local oscillators with x20 analog multipliers have fixed discreet references, but their phase noise performance is much better than the synthesized versions, an option that should be available.

2) Mixers are usually double balanced and (similar to driver amplifiers) are operated well below their compression point to preserve overall headroom.

3) High quality factor, coaxial tunable bandpass filters, as with all passive networks, should exhibit low VSWR and insertion loss with high enough order "N" to reject spurious products from the DBM (double balanced mixer). Agile designs can be of lower Q and of wider bandpass, but should also be low in VSWR and insertion loss.

4) Upconverter amplifiers are the first gain stages in a cascade and usually will have high gain and low noise. Because their inputs are in the micro-watt range at S-band, low noise HEMT devices followed by general purpose GaAsFETs are current state of the art.

Self-test diagnostics.

You should expect and demand that the diagnostic circuits and indicator panel convey useful, technical information. All critical amplifier functions should be monitored; lamps should warn of failure as well as state good and bad conditions, e.g. tricolor LEDs of red, yellow and green are offered in some designs. Beware of "light shows" or lamps that flash for no real diagnostic value.

Proven reliability.

The test of reliability is time. You should expect fast and courteous response from the manufacturer's service personnel; but, ideally you will not want to have to call on them. In addition to fundamentally reliable designs discussed previously, ask for and expect built-in protection components such as gate interlock system readyline, sequential power supplies, protection against antenna failure, etc.

Serviceability.

Ease of servicing the equipment is vitally important to continuity of operation and to maintaining peak performance. Operators of many systems, and particularly those in rural communities, fail to realize that good technical staff is difficult to find and /or retain. Sophisticated electronic test equipment is expensive and is usually not included in capital budgets. The ultralinear design, simple modulator philosophy minimizes service requirements. True self-test diagnostics and modular construction eliminate the need for sophisticated test equipment and ease the requirement for highly skilled technicians. Good, well thought-out designs should result in regular operational staff being able to maintain peak performance with built-in features.

Some manufacturers stress miniaturization and sacrifice ease of service, replacement of parts and good cooling. As noted previously, least cost and ease of service are a benefit of broadband modular construction. A reasonable trade-off should be made between conservative architecture that is easy for human hands, tools and test equipment to have access during service and yet still be relatively compact. Reliability and continuity of broadcast operations to the community are critical goals to be achieved.

You should insist that the manufacturer provide complete and comprehensive technical manuals with every shipment. Thoroughgoing block and level diagrams, parts lists, source lists and detailed schematics should be given to the owner of the proposed transmitter. One of a technician's greatest frustrations occurs when emergencies demand instant repairs or adjustments and the technician has no documentation to read, study or follow, and he is 8,000 miles or eight time zones away from the factory. To inform and educate the technical staff is a sound investment by both the owner and the manufacturer. Excellent technical manuals are not without cost, but the dividends of having them on site for routine or emergency use far more than offset the cost of preparation.

Growth.

MMDS operators will almost always wish to grow and extend the range of the system as installed. The system designer should select components such as transmitters, channel combiners and antennas (e.g. extra channel band-width, higher total signal power) that grow with the system without waste in the initial investment. If higher power amplifiers are anticipated in the future they should be designed for easy addition to existing transmitters. Stand alone, ultralinear power amplifiers that have all necessary internal protection components included, and that can be added to any brand of transmitter, is a major evaluation clue as to design philosophy. Beware of a manufacturer that requires so many interlocks and interconnections that performance cannot be guaranteed with any combination but its own transmitter and amplifier.

Multichannel transmitters

In this discussion we have focused on criteria for the evaluation and selection of single channel transmitters based on different design philosophies. A future article will be devoted to designing a multichannel transmitter, which is a simple broadband exciter, upconverter, amplifier combination intended for broadcast at low power over a small community.

As previously shown, reduction of IM3 in single-channel transmitters is a challenge not to compromise linearity; in multichannel transmitters the challenge is critical, since the third order products are so numerous and they are rising three times as fast as the fundamentals (see Figure 1). The low-cost amplifier design discussed earlier is not usable in multichannel service since some forms of precorrection are now impossible. Compromise designs are also not possible and amplifiers must be operated lower on the curve of linear response. The ultralinear design is favored by several dB as a fundamental application in this low-power service.

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