WIRELESS OR WIRED CABLE: COMPARABLE TECHNOLOGIES?

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ABSTRACT

A comparison between the performance of a 10 watt multichannel multipoint microwave distribution system (MMDS) and a simple cable system is provided. Comparisons are made of received signal level, carrier-to noise ratio and nonlinear distortion performance. MMDS system limitations and operational features are briefly discussed.

INTRODUCTION

As the cost of building a cable system continues to increase, operators continue to search for alternative technologies to deliver equivalent or better performance at lower costs. One alternative operators now have is to supply programming over a microwave multichannel multipoint distribution service (MMDS) and reduce the amount of cable plant. New FCC regulations have allotted sufficient frequency spectrum in the 2.5 to 2.7 GHz range to give operators the ability to offer an attractive number of channels.

Eliminating the need for a cable plant certainly proves MMDS to be less costly, but can the performance of an MMDS system meet or exceed cable system performance? The answer is yes. MMDS performance can meet and even exceed cable in fundamental performance areas like received signal level, carrier-to-noise ratio and nonlinear distortion products. Also, current equipment available to MMDS systems can provide many of the technical advances found in cable such as addressability, scrambling and stereo broadcasts. Combining comparable features and improved performance can make MMDS a successful complement to an existing cable system or a very competitive alternative.

PERFORMANCE

MMDS Received Signal Level

To begin, let us define a typical MMDS and cable system as shown in Figure 1. The MMDS system will utilize an omnidirectional transmitting antenna mounted 500 feet above ground level. For simplicity we will assume a constant receiving antenna height of 20 feet and a flat earth, realizing the farthest practical receive site distance will be limited to approximately 40 miles by the radio horizon. The detailed characteristics of the transmit and receive site equipment are listed in Table 1.

The received signal level can be calculated from the formula

$$P_R = P_T - L + G_T - L_P + G_R + G_B \qquad (1)$$

where

P_R = Received signal power at downconverter output (dbm)
P_T = Transmitter power (dbm)
L = Transmit site losses due to channel combining and waveguide losses (db)
G_T = Transmit antenna gain (dbi)
L_P = Free space path attenuation (db)
G_R = Receive antenna gain (dbi)
G_B = Block downconverter gain (db).

Typically, transmitter output powers will range between 10 and 100 watts. For this comparison, the transmitter output power will be 10 watts (40 dbm).

Losses between the transmitter and transmitting antenna depend upon the length and type of waveguide being used, whether adjacent channels are being transmitted and the number of transmitting antennas available. Non adjacent channels can be combined with passive waveguide combiners and incur

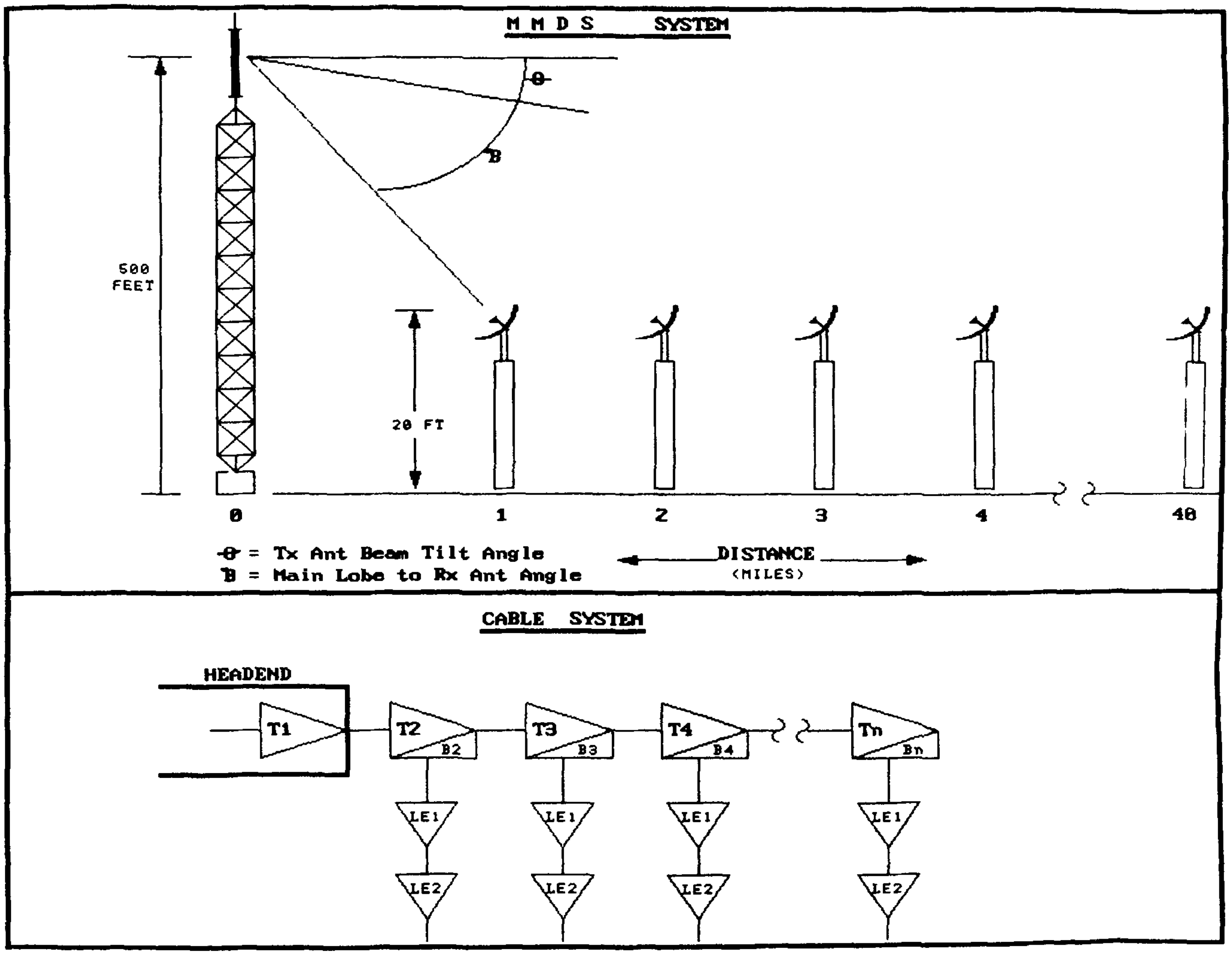

Figure 1. MMDS and cable system architectures.

only 1-2 db of loss plus the waveguide run losses. However, if adjacent channels are being transmitted and only one transmitting antenna is available, a minimum loss of 3 db plus the loss of the waveguide run must be incurred in order to combine the microwave channels. Utilizing more than one transmitting antenna to transmit adjacent channels will eliminate the hybrid combining problem. For this comparison, waveguide and combining losses will be assumed to be 3 db.

A variety of transmitting antenna patterns and gains are available. Standard omnidirectional antennas either horizontally or vertically polarized, can be obtained with gains from 10 to 17 dbi. Various cardioid patterns can be obtained with gains as high as 24 dbi. For this comparison, a typical omnidirectional antenna with 13 dbi gain was chosen.

Free space path loss can be calculated from the equation

$$L_P = 96.6 + 20 \log f + 20 \log d \qquad (2)$$

where f is in gigahertz (GHz) and d is in miles. The frequencies available for multipoint systems are 2.150 - 2.162 GHz and 2.5 - 2.686 GHz. For this comparison a median frequency of 2.6 GHz will be used.

The receive site consists of a receive antenna and a block downconverter to convert the microwave channels into the cable midband or

Freq (GHz) = 2.6
Tx Pwr (watts) = 10
Combining Losses (db) = 3
Tx Ant Gain (dbi) = 13
Rx Ant Gain (dbi) = 21
BDC Gain (db) = 20
Rx Ant TE (Kelvin) = 150
BDC NF (db) = 5.00
Tx Ant Height (ft) = 500
Tx Ant Tilt (degrees) = 0.5
Typ Rx Ant Height (ft) = 20

BDC Noise Factor	3.16
BDC Noise Temp	670.16
System Noise Temp	820.16
Noise Power BDC Output	-8.34E+01

Distance (miles)	Path Loss (db)	Rx Level (dbm)	C/N (db)	Tx/Rx Ant Angle (degrees)	Elevation Pattern Attn (db)
0.5	98.88	-28.88	54.56	-9.80484	-21
0.75	102.40	-26.90	56.54	-6.41122	-15.5
1	104.90	-30.40	53.04	-4.69442	-16.5
1.5	108.42	-21.22	62.22	-2.96822	-3.8
2	110.92	-21.42	62.02	-2.10256	-1.5
3	114.44	-23.94	59.50	-1.23570	-0.5
4	116.94	-26.19	57.25	-0.80195	-0.25
5	118.88	-28.13	55.31	-0.54162	-0.25
6	120.46	-29.46	53.98	-0.36805	0
7	121.80	-30.80	52.64	-0.24405	0
8	122.96	-31.96	51.48	-0.15106	0
9	123.98	-32.98	50.46	-0.07872	0
10	124.90	-33.90	49.54	-0.02085	0
15	128.42	-37.42	46.02	0.152757	0
20	130.92	-39.92	43.52	0.239566	0
25	132.86	-41.86	41.58	0.291652	0
30	134.44	-43.44	40.00	0.326376	0
35	135.78	-44.78	38.66	0.351180	0
40	136.94	-45.94	37.50	0.369782	0
45	137.96	-46.96	36.48	0.384251	0
50	138.88	-47.88	35.56	0.395825	0

Table 1. MMDS system characteristics used in analysis.

superband frequency range. The receive antennas typically have gains in the range of 18 to 30 dbi. A variety of block downconverters exist with gains ranging from 20 to 40 db and noise figures from 2 to 5 db. For this comparison, a receive antenna gain of 21 dbi, a block downconverter gain of 20 db and a downconverter noise figure of 5 db will be used.

The calculated received signal levels are shown in Table 1 for distances of .5 to 50 miles from the transmit site. The perturbations in level from .5 to 1.5 miles out are caused by the elevational pattern characteristics of the transmitting antenna as shown in Figure 2.

MMDS Noise Performance

The carrier-to-noise ratio (C/N) at a given receive site can be obtained by comparing the received carrier level calculated in Table 1 to the noise level present at each receive site. The noise level at each site will remain fixed assuming the same receiving antenna and block downconverter are used. Therefore, the noise level at each receive site can be calculated from

$$N_R = kBT_EG_P \qquad (3)$$

where

N_R = Noise power at downconverter output (dbm)

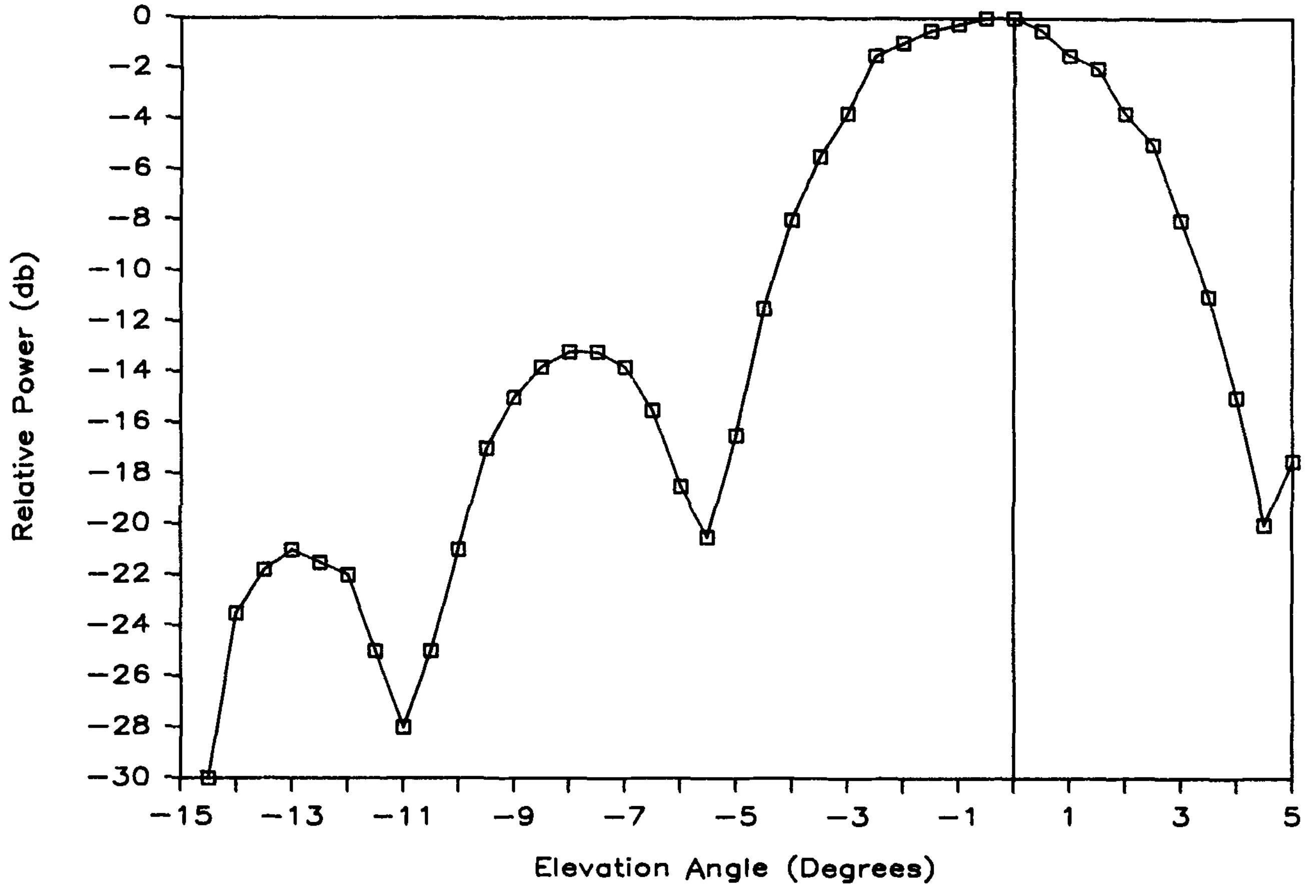

Figure 2. Transmitting antenna elevational characteristics.

k = Boltzmann's constant (1.38 x 10^-23 J/K)
B = Bandwidth (4 x 10^6 Hz)
T_E = Effective noise temperature of receiving system
G_P = Block downconverter gain (power ratio).

With the receiving antenna and block downconverter characteristics shown in Table 1, the effective noise temperature of the receiving system is approximately 780K and the noise level at the output of the block downconverter from equation (3) is -83.7 dbm. Table 1 shows the resulting C/N for the various receive sites in the MMDS system.

Cable System Noise Performance

The cable system design consists of a series of feedforward trunk amplifiers with a generous 2600' of separation. Each trunk amp breaks off into feeder legs consisting of a bridger amplifier and two line extenders. The performance levels at the output of this second line extender will be compared with the MMDS performance levels at the block downconverter output. The amplifier characteristics are listed in Table 2.

The C/N ratio can be calculated for the trunk, bridger and line extender systems independently using

$$C/N = P_R - G_A - NF - 10 \log N + N_O \qquad (4)$$

where

P_R = Received signal level (dbm)
G_A = Amplifier gain (db)
NF = Amplifier noise figure (db)
N = Number of amplifiers
N_O = System thermal noise level, -59.1 dbm for a 4 MHz bandwidth

and then combined using

Trunk Amp #	Distance (miles)	C/N @ Trunk Amp Output	C/N @ Line Ext Output
1	0.49	59.10	54.49
2	0.98	56.09	53.20
3	1.48	54.33	52.20
4	1.97	53.08	51.40
5	2.46	52.11	50.72
6	2.95	51.32	50.13
7	3.45	50.65	49.61
8	3.94	50.07	49.15
9	4.43	49.56	48.73
10	4.92	49.10	48.35
15	7.39	47.34	46.82
20	9.85	46.09	45.70
25	12.31	45.12	44.80
30	14.77	44.33	44.06
35	17.23	43.66	43.43
40	19.70	43.08	42.88
50	24.62	42.11	41.95
60	29.55	41.32	41.18
70	34.47	40.65	40.53
80	39.39	40.07	39.97

Trunk Amp :
Gain = 26.00
NF = 10.00
C/N = 59.1

Bridger Amp :
Gain = 31.00
NF = 9.50
C/N = 59.60

Line Ext :
Gain = 30.00
NF = 8.00
C/N = 62.1

Table 2. Cable system characteristics used in analysis.

$$C/N = -10 \log \{10^{(.1\ C/N_T)} + 10^{(.1\ C/N_B)} + 10^{(.1\ C/N_E)}\} \qquad (5)$$

where

C/N_T = C/N for the trunk cascade (db)
C/N_B = C/N for the bridger amp (db)
C/N_E = C/N for the line extender cascade (db).

The C/N was calculated for distances out to 40 miles (80 trunk amplifiers) and the results are shown in Table 2.

Figure 3 is a comparison of the C/N performance of the cable and MMDS systems. The results show that even at 10 watts of output power, MMDS performance can rival cable performance out to distances of at least 23 miles (47 trunk amplifiers).

Now, the results shown in Figure 3 describe the ideal situation where the C/N is only limited by the signal level received at each receive site. For systems of 2 to 16 channels in size this level of performance is quite practical. However, when the number of channels increases to beyond 16, the downconverter dynamic range will typically limit the maximum allowable received signal level and thus will be the controlling factor for C/N. The received signal level must be chosen to balance between C/N and nonlinear distortion performance. This is especially true for clear line-of-site receive sites out to distances of 20 to 25 miles.

Nonlinear Distortion

As previously mentioned, the downconverter dynamic range will typically be the controlling factor for the system nonlinear distortion performance. The architecture of the MMDS transmitting system is optimized for minimum distortion generation. An individual transmitter is used for each channel and channels are combined through the use of passive waveguide combiners. Cross modulation and intermodulation numbers of -60 db are very typical at the output of the transmitting antenna(s). Therefore, the downconverter is the only active element in the system handling the combined power of all channels. Because of this, the downconverter input level must be kept within the manufacturer's specified dynamic range to insure intermodulation and cross modulation performance on the order of -55 to -60 db as delivered to the subscriber. Obviously, this adjustment of received signal level will ultimately affect the C/N ratio.

Cable systems have a much more severe problem with nonlinear distortion because of the number of active devices

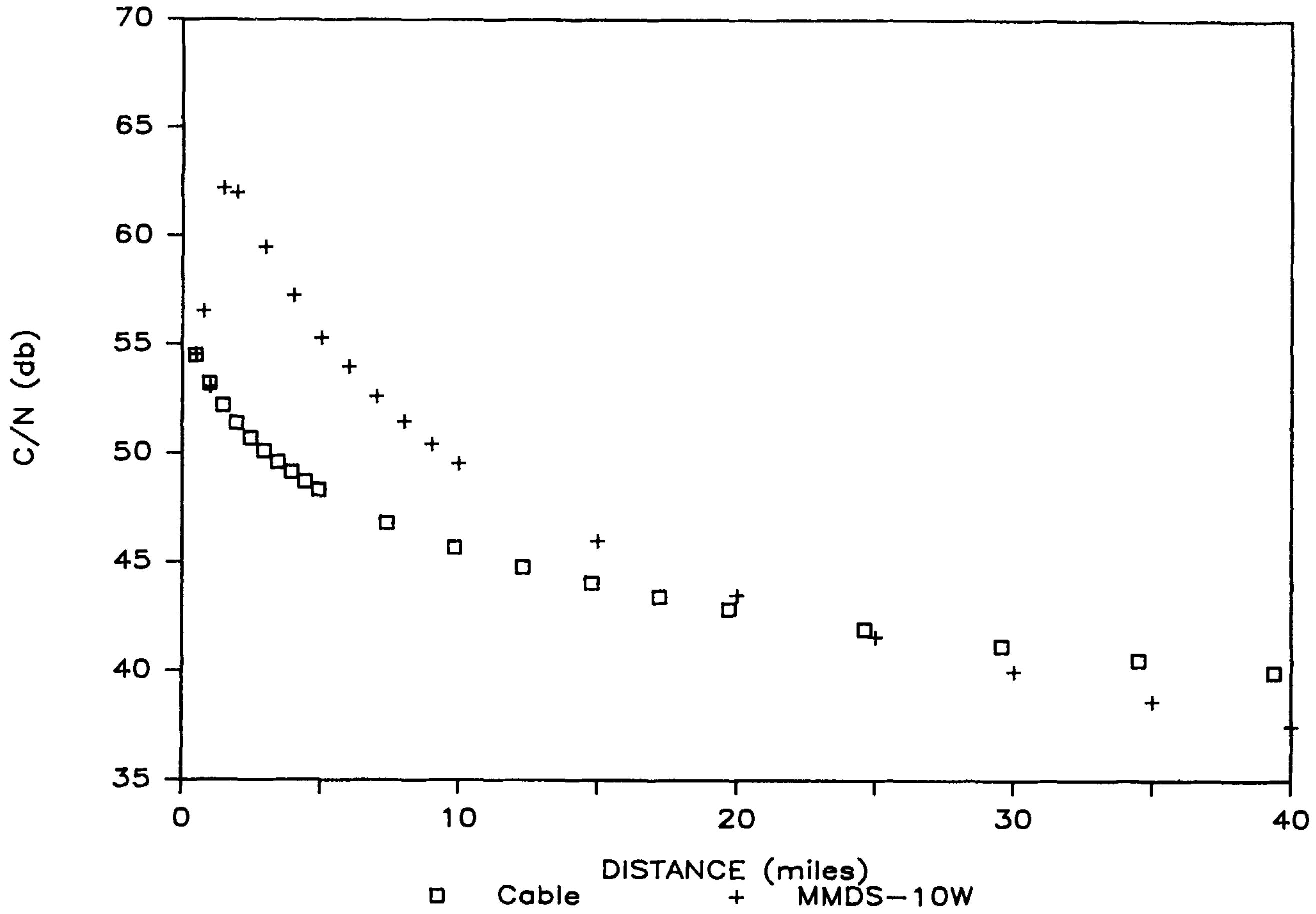

Figure 3. 10 watt MMDS versus cable carrier-to-noise performance.

handling all of the video channels. Cross modulation, intermodulation and composite triple beat worsen through every amplifier. The major contributor to nonlinear distortion products in a cable system are the feeder lines containing the bridger amplifiers and line extenders. These amplifiers typically have 20 to 30 db worse distortion figures than the trunk amplifiers. Because the cable system model used in this comparison contains only two line extenders and one bridger amplifier per trunk amp, the cross modulation calculations result in excellent performance. However, unlike MMDS, distortion products increase as the cable system grows.

MMDS Limitations

As described above,. MMDS can have significant performance advantages over cable. However, there are limitations placed on MMDS because it is an over-the-air technology. Because of the transmission frequencies (2.1 to 2.7 GHz), MMDS is essentially a line-of-site technology. Receive sites with totally or partially obstructed views of the transmitting antenna may have tremendous variations in received signal strength. Receive sites surrounded by foliage may experience large signal level fluctuations as the seasons change. It is essential to insure clear line-of-site between transmit and receive sites in order to obtain consistent performance at all times.

However, these problems with terrain and obstructions can be managed. There are signal strength contour studies available which will predict the amount of loss an MMDS operator can expect from terrain. By combining these studies with intuitive reasoning regarding other structures in the propagation area and foliage, an MMDS operator can predict his coverage area very accurately.

OTHER MMDS ADVANTAGES

Not only can MMDS offer performance advantages over cable, but also increased system reliability. Since there is no closed distribution system and no large cable plant to maintain, the only equipment reliability concerns exist at the transmit site and the subscriber's home. Also, the current design trend for MMDS transmitting equipment is away from tube technology and towards solid state devices. Solid state technology is more reliable and less power consuming.

The receive site antenna and downconverter are designed to reside on the subscriber's roof and provide excellent reliability in a variety of weather conditions. However, the potential weak link in the receive site installation can be the interconnections from the downconverter to the antenna and into the subscriber's home. Care must be taken to insure all connections are sealed and weather tight. The ingress of moisture into these interconnections can have considerable impact on received signal quality.

Other significant MMDS advantages include the speed at which a system can be built. Once transmit site construction begins, it is not unusual to be ready to install subscribers in a 1 to 3 month time frame anywhere in the potential coverage area. This is significantly better than the typical cable start-up times. Also, there is significantly less up-front cash needed to start a system as the major cost comes from subscriber equipment, not transmission equipment or plant.

BELLS AND WHISTLES

Transmission and reception equipment currently available to MMDS operators offers many of the cable system operational features and more. Signal security, addressability, stereo compatibility and spectrum space for ancillary data services are all available in MMDS.

From a security standpoint, both audio and video scrambling techniques are available. Current techniques consist of video inversion, sync suppression, bandwidth compression and combinations of these.

Addressability is performed through the use of in-band data transmission. Current techniques involve transmission in either the video or audio paths. Along with addressability come features like pay-per-view capability, flexible tiering and combining of programming, channel mapping and increased deterrents to pirating of signals and converters.

Since most MMDS equipment is designed to handle the additional audio bandwidth for BTSC stereo, the system is stereo transparent from the beginning. With the addition of stereo encoders at the transmitter site and decoders in the home, subscribers can enjoy excellent quality stereo sound.

CONCLUSIONS

A well designed and well managed MMDS system can exceed cable system performance in the fundamental areas which significantly impact subscriber satisfaction. Through careful and detailed system design, MMDS can achieve an excellent reputation as a high quality and high performance broadcast service. Also, since MMDS operators do not have an expensive distribution system to maintain, more attention can be paid to customer service and satisfaction. However, it is important for an MMDS operator to understand the technical capabilities and limitations of his system. With this understanding, an MMDS operator can build a successful and profitable business.

REFERENCES

1. Edward C. Jordan, "Reference Data for Engineers: Radio, Electronics, Computer, and Communications", Seventh Edition, Howard W. Sams & Co., Inc., 1985.

2. John C. Cunningham, "Cable Television", Second Edition, Howard W. Sams & Co., Inc., 1980.

3. "Basic CATV Concepts", published by Theta-Com CATV/Texscan.