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Modulation and Coding Used By A Major Satellite Communications Company

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ABSTRACT

Hughes Communications Inc. is a major satellite communications company providing or planning to provide the full spectrum of services available on satellites. All of the current services use conventional modulation and coding techniques that were well known a decade or longer ago. However, the future mobile satellite service will use significantly more advanced techniques. JPL, under NASA sponsorship, has pioneered many of the techniques that will be used.

THE COMPANY

Hughes Communications, Inc. owns and operates nine satellites, and has marketing rights to three more. The fleet is being expanded through launches and operating agreements, and by the end of 1989 HCI will own or have marketing responsibility for 12 satellites in orbit plus two more awaiting launch on the ground. The company owns and operates three Leasat satellites, with a fourth to be launched in the fall of 1989. The company also owns the three Galaxy C band satellites, the three Westar C band satellites, and a spare C band satellite on the ground. HCI also has marketing rights to the SBS K band satellites. Two are in orbit and the third will be launched next year.

The modulation and coding used on these nine satellites is representative of that used in the fixed satellite service industry as a whole.

CATEGORIES OF CUSTOMERS

HCI's customers have use commitments that vary from transponder ownership for the life of the satellite through half-hour transponder rentals to transmission of a single data packet. The Galaxy I satellite is used almost exclusively by cable TV broadcasters who purchased "condominiums" of transponders and actually own hardware on the satellite. On the other satellites, there are a number of companies who have long term leases of groups of transponders, single transponders, or partial transponders. Some of these operate their own networks while others pay for end-to-end turnkey service. HCI also has a substantial business in leasing transponders by the hour to broadcasters for sporting events and to companies that provide services such as video conferencing.

In the near future, HCI, as an owner of the American Mobile Satellite Corporation, will be offering mobile packet data services to trucking companies and others requiring short paging, position, or status message transmissions. These users will pay by the packet. In the early 1990's, mobile digital voice service will be offered to the general public as a compliment to cellular radio service.

INVENTORY OF CODING AND MODULATION

Analog modulation fills the majority of the C band satellite transponders. FM transmission of NTSC TV is used with a single carrier per transponder. There is also a small amount of FM/FM telephony and a few FM audio broadcast feeds.

The digital modulation falls into four groups:

- 60-Mbps, QPSK telephone trunk modulation;
- Single or double 1.544-Mbps T-1 modulation;
- 300-bps to 56-kbps VSAT BPSK or QPSK modulation; and
- 150-bps to 19.2-Kbps spread-spectrum modulation.

The 60-Mbps telephone trunk modems use QPSK and occupy a full 34-Mhz transponder. As required by telephone practice, they are operated at a 10^{-7} BER. The links have a large margin to provide a high link availability. Error correction coding is not necessary because of the high link margins designed into the telephone system. These modems are available off the shelf from several companies. The technology needs for this service are generally well met. Relatively few of these modems are purchased every year.

The T-1 network modems are also operated at a 10^{-7} BER. The modems offer rates from 56 kbps to 3.152 Mbps and coding rates of 1/2, 3/4, or 7/8 convolutional coding. Typical link margins are 5 dB above the 10^{-6} BER requirement. Organizations currently purchasing these modems are concerned primarily with cost and number of features offered. The technology needs are well met. The total number of T-1 modems in use on satellite circuits is probably in the hundreds.

The VSAT modems business is booming. There are tens of thousands now in use and thousands more are being sold every year. These modems use rate 1/2 coding to provide a 10^{-7} BER on links with very little margin. This market is also cost and features driven; technology is not an issue.

Spread spectrum modems are used extensively. There are thousands of these modems now in service. A 2.456-Mcps direct sequence modulation is used to mitigate interference to/from adjacent satellites or terrestrial microwave stations. A broadcast service is offered at 19.2 kbps and an interactive service is offered at 153.6 kbps on the outbound link and 1200 bps on the return link. Spread-spectrum modems are also used by a position-fixing service that transmits spread-spectrum ranging signals simultaneously from three or four satellites. The data rate is only 150 bps because only information attendant to the position fixing function is transmitted.

The mobile packet data modems will use BPSK at 300 or 600 bps. Rate 1/2 convolutional coding is used. The modems are designed to be compatible with INMARSAT Standard C. This same modem design will be used in a worldwide market. Only a few prototype modems now exist but several thousand are on order. By the mid 1990's hundreds of thousands of these units will be in use.

There is a competing packet data service that uses SSMA. This system uses a combination of frequency modulation, frequency hopping and direct sequence modulation to mitigate against adjacent satellite interference. The data rate is 22, 44, or 32 bps with rate 1/3 coding in the hub-to-mobile direction and 4960.3 bps with rate 1/2 coding on the return link.

In the future, a mobile digital voice service will be offered. Final modulation and coding techniques have not yet been determined. Voice coding to 4800 bps will be standard, while 9600-bps voice coding will be offered at a higher cost. The highest performance modems demonstrated to date have been designed and tested under NASA sponsorship at JPL. Those modems use rate 7/8 trellis coded 8DQPSK to provide 4800-bps service in a 5-kHz channel.

Consideration is also being given to providing mobile digital voice services with direct-sequence spread-spectrum modulation. Services using 8-Mcps QPSK with rate 1/3 convolutional coding have been demonstrated. Services using 1 to 2- Mcps rates are also being considered.

NASA sponsored a conference on mobile FDMA and CDMA architectural issues at JPL in March of 1989. Papers presented showed that CDMA allowed substantially more satellite capacity than FDMA. System operators are currently evaluating the conference results.

OBSERVATIONS REGARDING C BAND AND Ku BAND MODEMS

The modulation and coding technology used in the the C band and Ku band fixed satellite services is quite mature. Engineers specifying modems are generally more concerned with special features, cost, and delivery than getting the last fraction of dB performance. For all services except the 60-Mbps telephone trunk services, satellites generally have more bandwidth available than required. The satellites' power is not great enough to support the number of carriers required to fill the bandwidth. The next generation of satellites in the 1990's will have greater power and may fill the available bandwidth. More bandwidth efficient modulation and coding techniques will then be if the bandwidth is filled.

OBSERVATIONS REGARDING MOBILE SATELLITE TERMINAL MODEMS

NASA-JPL support of industrial R&D programs and propagation research has benefited U.S. industry. The work on modems and mobile antennas is the only U.S. source of performance data that can be used in system planning. The results of the work on radio propagation research has revolutionized the treatments of link margins. In 1985, 1988, and 1989, NASA conferences for industry have transferred Government-sponsored technology to the private sector and have encouraged the exchange of ideas between conference participants. The timing of R&D programs has been excellent. NASA sponsored the effort early enough for U.S. industry was able to do the early research leading to products, but not so early that the technology was obsolete by the time markets were developed.

SUMMARY OF MODULATION AND CODING NEEDS AND OPPORTUNITIES

In summary, the current modulation and coding needs of commercial fixed satellite services are well met by industry. However, the next generation of satellites will require a new generation of modems which will then be available from industry.

In contrast, the modulation and coding needs of mobile satellite services are not currently being filled. Since standardization of modulation and coding techniques will be finalized by 1991, there is still room for innovative new techniques to be accepted for the first generation system in the next two years.