SYSTEMS ANALYSIS AND DESIGN FOR AN OPTICAL FIBER SYSTEM FOR CATV APPLICATIONS

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ABSTRACT

The arrival of fiber optical cable upon the communications scene is recognized as a practical reality. The advantages of optical fiber cables for CATV Trunk application are weighed against conventional coaxial cables for transporting multiple Television Channels.

Available optical fiber constructions are discussed. Their use in CATV Trunk application is described and the advantages are outlined.

Availability of terminal devices to produce a "live" working trunk line is considered and the economic impact of the "in-place" working system is noted.

INTRODUCTION

This paper examines the use of optical fiber technology as applied to CATV trunk-lines. Candidate practical systems using lasers, graded-index fibers and PIN diode detectors are examined. System performance is predicted and handling of the equipment is described. Amplifier spacing, bandwidth capability and unique characteristics of optical fiber technology are also discussed.

FIBER OPTIC CABLE

Fiber optic cable is currently available in single or multifiber construction. These cables, ranging in size from 0.150 to 0.250 inches in overall diameter, have the ability to transmitt RF signals of as much as 300 MHz Bandwidth on an optical carrier with as little 12 db per mile loss.

Three types of fiber can be used, their application being dictated by the bandwidth requirement. Step index fiber can be manufactured having very low loss but bandwidth is sacrificed. Semigraded and graded index fiber are applicable to wider bandwidths. The glass fibers now manufactured are capable of developing tensile strength in excess of 300,000 PSI and as a consequence can be subjected to the exacting environmental requirements of CATV use.

AMPLIFIER TECHNOLOGY

Technological break throughs in laser configuration now make it possible to discuss Fiber Optic analog TV signal transportation systems with at least 12 Channel capacitites.

These lasers operating, at an output of approximately 3 MW, Optical Power at room temperature, have mean time to failure ratings of 100,000 hours. Future development is expected to yield devices with mean life expectancies of 1,000,000 Hours. Solid state thermoelectric devices capable of controlling laser temperature within $\pm 2^{o}$ C are in existence today and are compatible with overall amplifier designs.

The electronic techniques for modulation, linearization of the laser output and the detection of low level light signals are a reality.

Therefore it seems pertinent that one should consider a fiber CATV system.

SYSTEM THEORY

The quality of a communications system is determined by the degradation of its signal-to-noise ratio from the system input to the system output. The signal-to-noise ratio is given by:

$$S/N = \frac{P}{N_q + N_t}$$

Where P = Detector Output Power
N_q = Quantum Noise Power
N_t = Thermal Noise Power

These quantities can be calculated as follows:

$$P = a^2 P_s^2 G^2 M^2$$

$$N_q = 2eBG^2 R (aPs + I)$$

$$N_t = 4 FKTB$$

Where A = Detector responsivity in amps/watt (typically 0.55)

P_s = Required power at the receiver in watts

R = Load resistance in OHMS
G = Gain
e = Electron charge in Coulombs
B = Bandwidth in Hertz
I = Effective dark current in Amps
F = Noise figure of the preamplifier
K = Boltzman's constant in Joules/^oK
T = Temperature in ^oK
m = Ratio of lumininance to composite video = 0.7

For a conventional coaxial cable system the Thermal noise (N_t) limits the maximum achievable signal to noise level. In an optical fiber link, the quantum noise (N_q) primarily limits the maximum achievable signal to noise level. Since the Quantum noise is usually mor significant than the thermal noise, the S/N equation reduces to:

$$S/N = \frac{a^2 P_s^2 m^2}{2e\ B\ (aP_s = I)}$$

As a first order approximation, the dark current is negligible and the signal to noise ratio is proportional to the received power divided by the bandwidth of the system. This ratio is multiplied by a constant which includes detector responsivity.

In order that many channels of Television be carried through a single optical fiber, it is necessary that the fiber, the light source, and the detector have sufficient bandwidth and signal strength.

The optimum optical fiber CATV Trunk Line system is judged to be the best balanced compromise between repeater spacing and number of channels per fiber for the required signal to noise ratio.

OPTICAL FIBER CATV SYSTEM

A CATV supertrunk-line or transportation link should deliver a signal to noise ratio of typically 53 db peak to peak luminance to RMS noise. A ten mile optical trunk system having thirty channels can be handled by a single multi-fiber cable. Available LED's can provide for five channels per fiber using semi-graded index fiber. Solid state lasers, currently in development can demonstrate twelve channel capability on a single graded index fiber. Continuing laser development promises devices capable of transporting as many as 30 channels over a single fiber. In both the LED and laser cases the detecting diode can be a P.I.N. type.

Using lasers to handle a 54-216 MHz conventional VHF Spectrum of twelve channels on a single fiber, some 12 repeaters would be required for a 10 mile run to maintain a 53 db peak-peak luminance to weighted noise. A three fiber cable could thus provide 30 channels.

The repeaters consist of P.I.N. diode receivers coupled to laser transmitters. Sufficient circuit gain is provided by the receiver to modulate the laser at the proper output power level.

For purposes of comparison, three hypothetical 10 mile systems can be laid out as follows:

Conventional	12 Ch. laser	30 Ch. laser
3/4" cable	3 Fiber 1/4" cable	1 fiber 0.15" cable
30 Amplifiers	12 repeater sets	12 repeaters
30 Channels	36 Channels	30 Channels

Each optical repeater occupies less than 5.0 cubic inches. A set of three repeaters will fit in a space dimensioned approximately 2.0" x 3.0" x 5.0". Repeater power requirements are less than 3 watts at 12 volt level, it is expected that power supplies can be provided on-site if pole line electricity is available.

It is anticipated that, because of the small size and light weight of both cable and amplifiers, system construction will be easier. Splicing will be accomplished by use of small, easy to install low loss connectors.

One should bear in mind that the fiber optic system, by its very nature, using a non conductor as a transmission medium, is, for all intents and purposes, immune to RF 1, EMI, lightning surges and ground loops. Additionally the system will not radiate RF energy.

Fiber optic cable has, for all intents and purposes, flat loss and its attenuation does not vary with ambient temperature variations. Sensitive AGC and equalization circuits are not necessary.

In summary, the technology is here. A competitively priced trunk system having significant overall advantages in performance and operating cost is now a reality.