In addition to not defining co-primary, the Commission has not established any interference criteria to protect co-primary users. As a practical matter, it will be impossible to impose an obligation on new users to negotiate with existing users or prevent interference to their operations until satisfactory interference criteria are developed. Further, it will be impossible to develop interference criteria without first knowing what technologies will be placed in the band, and yet by definition "emerging technologies" are at present unknown.

At a minimum, utilities and other existing 2 GHz private microwave users must be assured interference protection equal to or better than the level of protection now provided under Telecommunications Industry Association (TIA) Standard 10E. Otherwise, the reliability of utility communications would be degraded which would detrimentally impact overall utility service.

In view of the uncertainties over (1) the services and technologies that might use these bands; (2) the interference potential of these technologies; and (3) the ability of new technologies to share with existing fixed microwave systems, UTC reiterates that the "spectrum reserve" concept cannot be implemented as proposed. Nevertheless, if the Commission deems it necessary to "earmark" a band for use by new technologies, UTC urges the Commission to announce in this docket that any "new

technology" systems authorized in that band will be licensed only on a conditional secondary basis during the initial license term.[73/] That is, during the first 5 years a new technology licensee is authorized to use spectrum from the spectrum reserve, it must afford full and unconditional interference protection to existing facilities licensed on a primary basis. If, at the end of the initial license term (assumed to be at least 5 years), there are no unresolved interference problems, the new technology licensee could request co-primary status.

Under the approach suggested by UTC, existing primary users of the spectrum would be assured that they could terminate interference on a moment's notice, and that disputes would not develop over the burden of proof requirements between co-primary licensees. Since many new technology proponents have expressed optimism that their systems will not interfere with fixed microwave systems, conditional secondary licensing should not affect the development of new systems, and in fact, could help to ensure that the spectrum is being used carefully and efficiently. Further, the secondary status would not be permanent, but it would have be in place long enough to assure that a fully-developed new technology system will not interfere with an

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[73/] UTC assumes license terms for any new services will be at least 5 years.

existing fixed microwave system.[74] After successful operation on a non-interference basis, the new technology license could be upgraded to co-primary status.

C. Co-Primary Status Must Be Indefinite For All Users

As part of its transition plan, the Commission states that it recognizes the special economic and operational considerations involved in relocating state and local government agencies and therefore is proposing to exempt these entities' 2 GHz microwave operations from the mandatory transition period and instead will allow them to remain in the band on a co-primary basis indefinitely.

There is absolutely no technical basis for distinguishing between state and local government 2 GHz users and other users of the band. In fact, many 2 GHz systems are jointly owned, operated and relied upon by state and local governments and private sector utilities. Moreover, if, as the Commission proposes, all relocation costs are to be borne by the new technology users, then economic factors cannot be a "special consideration" for state and local government agencies.

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[74] Under several of the new technology proposals, the interference potential of a new service could not be fully understood until full deployment of the new technology equipment due to the cumulative nature of the interference.

Co-primary status must be on an indefinite basis for all 2 GHz microwave users.[75] It is unreasonable to expect all non-government licensees to accept secondary status, with no possibility of reimbursement, after an arbitrary time period of ten or fifteen years, or through a five-year phased-in approach. The Commission's proposed transition period is little more than a hollow gesture. The plan would put existing licensees in a position where they would have to relocate within a certain period of time or lose any ability to obtain reimbursement, and yet, during the initial five, ten or fifteen year transition period there may not be any new technology licensees in the existing user's operating territory to pay such relocation costs. Moreover, many new technology systems may not be implemented until after the initial transition period lapses,[76] which guarantees that these new technology licensees could force any existing user to relocate without paying any compensation for the forced relocation.

Furthermore, under the Commission's plan, existing licensees in rural areas are ostensibly protected, since the new

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[75] In any event, the Commission must clarify that indefinite co-primary status extends to all state and local government entities including public power utilities, and not just "public safety" agencies.

[76] See time projections for establishment PCN service and other forms of PCS contained in written testimony of Arthur D. Little submitted as part of the FCC's December 5, 1991, En Banc hearing on PCS, GEN Docket No. 90-314.

technologies are only expected to develop initially in urban areas. However, it is doubtful whether microwave equipment manufacturer will continue to build equipment and replacement parts for a service that only exists on a secondary basis. The 12 GHz band is a clear example of this situation. 12 GHz microwave operations were allowed to remain in the band on a secondary basis until displaced by a Direct Broadcast Satellite (DBS) system. Thus far there is no DBS service and yet 12 GHz microwave operations are virtually non-existent because the microwave equipment manufacturers stopped making equipment for the band. In addition, the FCC has no basis for concluding that new technologies will only develop in the urban areas, since, as noted above, the new technologies and services which may occupy this band have yet to be identified.

UTC is also opposed to the Commission's phased implementation approach that would allocate portions of the 2 GHz band in specific phases. Like the mandatory transition plan this approach will also relegate existing users to secondary status arbitrarily.

For all of these reasons, the Commission must modify its proposal to extend indefinite co-primary status to all 2 GHz microwave users.

D. Free Market Negotiations

All reasonable relocation costs for existing users of the 2 GHz band must be provided by the new technology licensees. Otherwise, the costs would be borne in large part by taxpayers and utility ratepayers.

UTC supports the concept of allowing voluntary negotiations between licensed 2 GHz microwave users and new technology service providers concerning reimbursement of relocation costs. However, as described above, a crucial element regarding the equities of such an arrangement is that all 2 GHz microwave users must be licensed indefinitely on a co-primary basis. In addition to ensuring that relocation costs will be borne by the new technology proponents, indefinite co-primary status would be necessary to enforce contracts entered into regarding continued microwave operations in the band after a certain time period.

UTC understands that the primary reason for the Commission's proposed time limitation on the co-primary status of non-government 2 GHz microwave operations is the concern that existing users will hold the spectrum "hostage" in order to seek windfall profits. As a practical matter it must be pointed out that the majority of the existing 2 GHz licensees use their microwave operations as a tool rather than for direct commercial gain and therefore have little incentive to make a profit from

them. In the case of utilities, for example, there would be no "windfall" because any monies received by a utility in connection with its relocation expenses would be applied above-the-line as "contributions in aid of construction," and would only benefit the utility's ratepayers, not its stockholders.[77] However, to the extent that there is concern over the feasibility of relying entirely on voluntary negotiations, UTC proposes that the Commission provide for an involuntary negotiation program, to commence fifteen years from the adoption of a specific allocation to an emerging technology. The program could be similar to the MMDS/ITFS relocation plan adopted in GEN. Docket No. 90-54. At a minimum such a plan should provide:

1. A new user may request involuntary modification of an existing user's license to specify operation on different frequencies;

2. The new user is responsible for all relocation costs, and must set up an escrow account or buy a performance bond to guarantee relocation costs;

3. The proposed system must provide equal or better reliability than the existing system;

4. The existing user has an opportunity to oppose the relocation proposal; and

5. If the new facilities prove to be unsatisfactory in practice, the user must be relocated back to its original facilities at the new user's expense.

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[77] In the case of municipally-owned utilities or rural electric cooperatives, the same would hold true because the ratepayers are, in essence the utilities' owners.

Under this proposal, voluntary negotiations would be utilized during the initial fifteen year licensing period of the new service and the involuntary plan would only be utilized in the rare situation where market forces could not work out an accommodation. Further, by delaying the effectiveness of this program until 15 years after licensing, it will ensure that the Commission is not inundated by requests to arbitrate involuntary negotiations.

As noted above, UTC proposes that new microwave systems should continue to be authorized in the 2 GHz band on a primary basis. However, to allay any concern that such systems would be installed merely to force a buy-out by new technology proponents, UTC proposes that those systems would be immediately subject to the above-described involuntary relocation procedures, and would in no instance be allowed to accept financial compensation in excess of reasonable compensation for a relocation to comparable communications facilities.

As a final matter, UTC is adamantly opposed to the introduction of emerging technologies in the 2 GHz band on a Part 15 unlicensed basis or any other basis where the existing users would be unable to identify the source of interference or to secure reimbursement for relocation costs. As stated earlier, the correct level of interference protection afforded to private microwave systems cannot be compromised. Unlicensed use is

incapable of providing this protection. If marketplace mechanisms are to be used to relocate existing users, then means must be available for readily identifying potential or actual interference sources and for holding those entities responsible for correcting interference or relocating licensed microwave systems. Unlicensed radio services would be incompatible with this type of market-based relocation plan, and must not be authorized in the 2 GHz band.

IV. Use of Emerging Technology Bands

In its NPRM, the Commission indicates that it proposes to commence separate rulemakings in order to determine the specific services that should be allocated spectrum from the spectrum reserve. In carrying out these various proceedings, UTC urges the Commission to be guided by a requirement that all proposed new systems must conclusively demonstrate the ability to operate without degrading existing systems in the band.

V. Conclusion

The spectrum reserve concept is a misguided effort to clear the 2 GHz band for unknown, future technologies. This process does not permit the requisite balancing of competing public interest factors, and does not satisfy the APA's requirements for reasoned rulemaking.

The NPRM, and the OET Study, are result-driven, and do not represent objective cost/benefit analyses of reallocating spectrum for new services. Under an objective analysis, the FCC would have targeted other bands where the impact on existing users would be far less, and where the impact on the American economy and core American business would be less substantial.

Despite the Commission's denials, the spectrum reserve concept is a band-clearing concept. There is nothing to distinguish this proposal from its clearing of the 12 GHz band for DBS, a service which, in 10 years, has yet to develop. Unlike the clearing of the 12 GHz band, however, the Commission has made no proposals for adequately accommodating displaced users in other frequency bands. Aside from offering a "blanket waiver" of legal eligibility, the Commission has not even undertaken a review of the usefulness of other bands as presently configured, nor proposed any changes in the proposed replacement bands.

Since the "new technologies" that might be allocated from the spectrum reserve have not yet been identified, it is impossible for existing users to accept the notion of "co-primary" status. The Commission has not defined how co-primary status would be interpreted as between disparate services sharing a band, nor what interference or sharing criteria would be established for these new, unknown services. UTC therefore

recommends that if new services are permitted to share a band, the new service licensees should be authorized only on a secondary, non-interference basis during at least the initial 5-year license term. Further, all existing service users should be permitted to remain in the band on a primary basis indefinitely, and should be permitted to continue licensing new systems on a primary basis.

Marketplace negotiations should be permitted if new technology licensees find it necessary to relocate existing users. However, because marketplace negotiations would not be feasible in the context of unlicensed facilities, such "Part 15"-type services should not be allocated for use in a spectrum reserve.

WHEREFORE, THE PREMISES CONSIDERED, the Utilities Telecommunications Council respectfully urges the Commission to terminate this proceeding, or, in the alternative, to issue a Further Notice of Proposed Rulemaking which makes specific proposals on which interested parties will have a meaningful

opportunity to comment with respect to the issues surrounding a reallocation of spectrum for new technologies.

Respectfully submitted,

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ATTACHMENT A

The Merging of Photonic and Microwave Technologies

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Kyoto, Japan

Introduction

ATR Optical and Radio Communications Research Laboratories, one of four distinct corporations within the Advanced Telecommunications Research Institute International, is devoted to research and development in communications technologies that will have crucial impact on the future. In their research on optical intersatellite communications, advanced array antennas, optical and electronic devices and mobile communications, these laboratories combine the talents of an international staff and their modern facilities to realize some highly advanced telecommunication systems.

Two fundamental technologies currently pursued in these laboratories are microwave monolithic integrated circuitry (MMIC) and fiber-optic (FO) signal-distribution architectures. One vision aims at synthesizing these two technologies for use in personal communications. A future result of this new technology could be wristwatch-sized telephone/televisions and the signal distribution networks required to service them.

Personal communication systems of the future will have to be adaptable, user convenient and versatile. Further miniaturization of handsets will aid in convenience, yet, because of the reduced available transmitting power, will also require a more compact micro-cellular distribution network operating at higher carrier frequencies. In turn, this poses problems in the distribution of mm-wave communication signals over a moderately distanced but crowded network. Additionally, the ability to miniaturize the portable terminals further requires more innovative MMIC design solutions.

Within these laboratories, the Radio Systems Group has been assigned to address problems related to future personal communication components and systems. Notable contributions have been made in the integration and miniaturization of MMIC-based functional subsystems. Specifically, by the use of coplanar line line-unified-FETs (LU-FETs) and multilayer structures, the miniaturization of circuit function blocks has been realized. With regard to FO distribution links, research is being carried out not only to design specialized architectures capable of transmitting mm-wave signals on optical carriers, but also to evaluate them on the basis of their performance and the feasibility of system integration.

Concept of the Future

The key to success in personal communication technology lies in the ability to offer cost-effective, multiservice communication pathways to the subscribers. The trend of shrinking handsets and more reliable connections has spurred the proliferation of services such as cellular telephones, paging networks and mobile radios. If telecommunication systems continue to follow similar trends, then further miniaturization of the portable terminal is inevitable.

While the dimension of the portable terminals should be as small as possible, this decrease in size curtails the available power for data transmission. This suggests the use of mm-wave bands for data transmission to take advantage of smaller feature sizes. Novel miniaturized MMIC-based antenna designs and advances in device technology are needed before these goals can be realized. Figure 1 is a conceptual drawing of a system incorporating such portable terminals. The micro-cellular zones that receive from and transmit to the portable terminals must be scaled down to receive the portable terminal's transmissions. This increase in density contrasts with current cellular telephone configurations. The only viable trans-

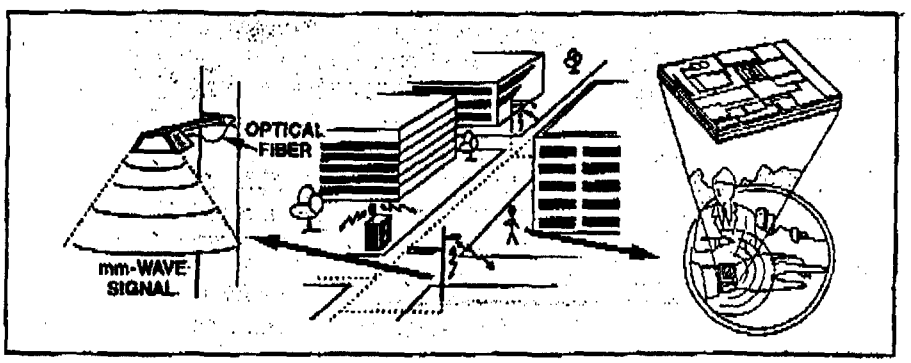

Fig. 1 A conceptual diagram of a system that incorporates portable terminals.

mission lines with such density in the mm-wave bands are FO links. If small sized and low cost systems are to be realized successfully, the concurrent utilization of both photonics and microwaves will be necessary.

MMIC Technology

Key to the success of the development of technologies for multifunction and reduced sized MMICs has been the LUFET concept. Conceived in 1987, this design integrates microwave coplanar transmission lines directly into the FET structure, thus eliminating the need for impedance matching and the use of large quarter wavelength tranmission lines in some circuits.[1]

With the LUFET, circuit layout is greatly simplified, resulting in a reduced-size circuit with little or no degradation in performance over that of conventional designs. From this concept came the realization of a host of basic circuit function modules, including multiport power combiners and dividers, mixers, balanced modulators, signal path switches, circulators, frequency doublers, phase inverters and active inductors.[2,3] Performance of these circuits has been demonstrated beyond 20 GHz. Examples of LUFET circuits are shown in Figure 2. A LUFET-based impedance transformer from coplanar to slotline is shown in Figure 2a. Additionally, a LUFET wideband magic-T and a broadband amplifier are shown in Figures 2b and 2c, respectively.

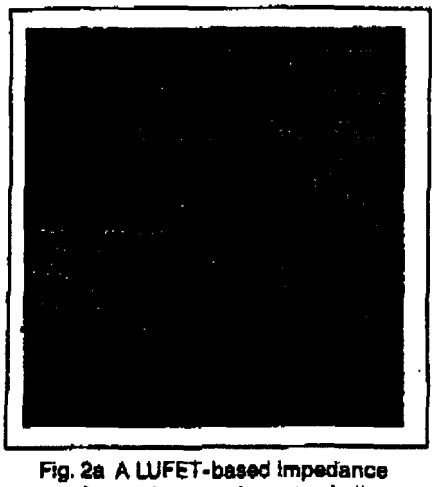

Fig. 2a A LUFET-based impedance transformer from coplanar to slotline.

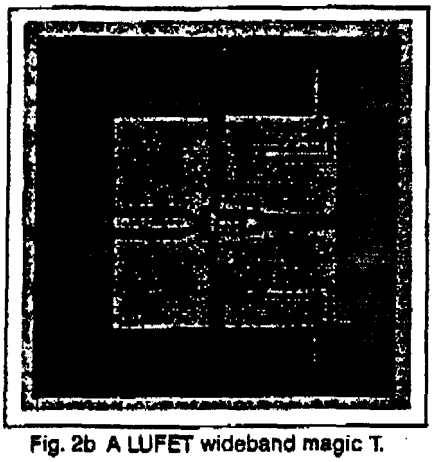

Fig. 2b A LUFET wideband magic T.

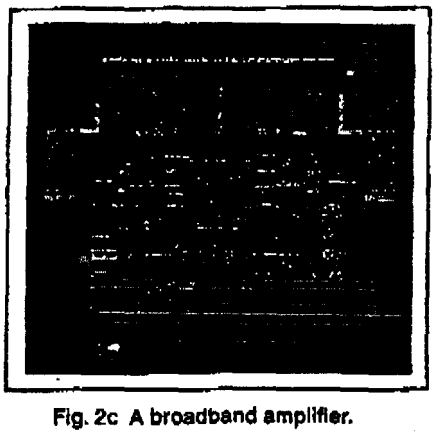

Fig. 2c A broadband amplifier.

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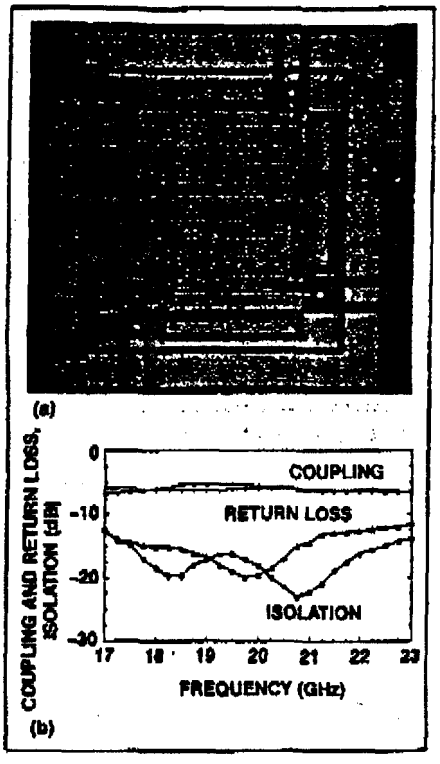

Fig. 3 (a) A photograph of the multilayer branchline coupler and (b) its measured performance.

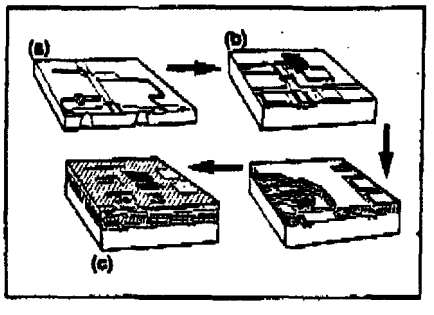

Fig. 4 A comparison of (a) planar, (b) multilayer and (c) three-dimensional architectures.

Major advances in multilayer MMIC circuitry has also been accomplished.[5] Through the use of thin dielectric film layers over conventional substrates, multilayer structures such as magic-Ts, rat-race and branchline hybrids, Wilkinson power dividers, slow wave structures and distributed amplifiers are realized in an area that is significantly smaller than that used in conventional uniplaner MMICs. The multilayer branchline hybrid coupler, shown in Figure 3a, requires 50 percent less area than the corresponding planar hybrids. Its performance is shown in Figure 3b.

The ability to build three-dimensional MMICs, shown in Figure 4, will greatly aid in the overall decrease in chip size. The anticipated consequences will be higher wafer yields, greater reliability as well as large scale integrated circuits with more functions per unit area. One recent achievement is a miniaturized, ultra-wideband balanced upconverter. This new design incorporates line unified HEMT modules as well as multilayer microstrip lines. Performance characteristics are shown in Figure 5. The most notable features of this design are the broad bandwidth (3 to 31 GHz) and a fourfold decrease in circuit size. This one example further demonstrates the potential for high performance and compact MMIC based systems.

Novel low loss transmission line structures that permit the fabrication of compact circuit blocks are being investigated. One such new structure, the valley microstrip line, has a 20 percent lower insertion loss than standard microstrip lines of equal widths. This structure is fabricated by taking advantage of the unique etching angle of spun polyimide

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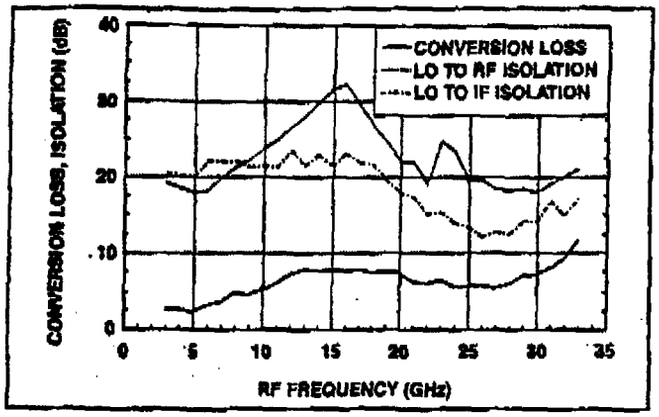

Fig. 5 Performance of the miniaturized, ultra-wideband balanced upconverter.

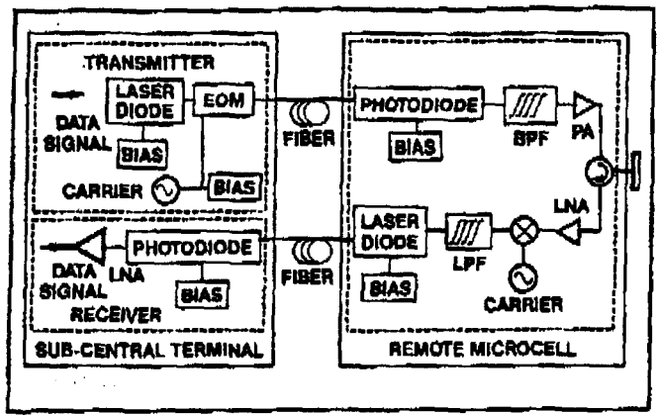

Fig. 6 A schematic diagram of an FO link based on an $LiNbO_3$-based EOM.

films and by employing the lift of technique of circuit metalization.[6] The LUFET-based multilayer circuit structures and novel low loss lines provide a solid foundation in MMIC technology that is well suited for the chip level integration of optical components.

Fiber-Optic Technology

Within the past two years, increased attention has been directed to the requirements and methods of signal distribution in future microcellular communication systems. The primary goal involves the development of novel FO link architectures that incorporate the desirable features of conventional links, yet will be able to be manufactured and operated economically at mm-wave frequencies. Cost is still a prohibitive factor in the high speed FO market, mainly due to the limitations of laser diode and external modulator technology.

In currently available lasers or external optical modulators, optical modulation bandwidths rarely exceed Ku-band, and they are limited by optical transmitter performance. Specifically, the high frequency performance of semiconductor laser diodes and electro-optic modulators (EOM), with the exception of unique laboratory specimens, are still lacking. Furthermore, the prohibitively high cost, general availability and poor reliability of optical transmitters at mm-wave frequency present a problem for applications requiring high speed fiber-optic links. Therefore, to overcome these problems, alternative FO link architectures are studied.

Several methods of producing carrier frequencies beyond the fundamental laser diodes or EOMs have been proposed and investigated. These methods include mode locking of laser diodes;[7] generating mm-wave beat frequencies between two tunable lasers;[8] using the laser diode's nonlinearity to upconvert data signals (laser diode mixing);[9] using the photodiode's nonlinearity to up or downconvert data signals, also using the harmonic frequencies can produce substantial bandwidth improvement;[10] high frequency narrowband electro-optic modulation;[11] simultaneously using direct laser modulation and narrowband carrier modulation on EOMs for upconverting data signals;[12] and utilization of laser diode harmonics by using large modulation indices.[13]

Although all these methods can potentially produce mm-wave carrier frequencies, each one has its particular limitations in performance and practicality. Generally, methods that require complex optics or device stabilization are not well suited for commercial applications.

Currently under investigation are $LiNbO_3$-based EOMs with traveling wave and resonant electrodes, which require low driving power. The device operates at very high frequencies, but in a very narrow frequency band. A schematic diagram of a FO link based on this device is shown in Figure 6. In this link configuration, the data stream is used to modulate the laser diode. The modulated laser light is then amplitude modulated by the EOM at the mm-wave carrier frequency. Simple filtering at the receiver will allow usage of either the carrier, data or the upconverted sideband frequencies. Reliability is increased and signal distortion from the EOM Low link insertion loss can be realized from the single frequency, low drive power EOM design.

A critical factor in the personal communication market will be the ability to distribute information effectively. Low loss mm-wave fiber-optic links provide the best solution for bringing information and new services to consumers. Through the combination of optical and microwave functions on the same substrate, small and economical optical-MMIC (OMMIC)-based T/R modules should be realizable.

Merging Technologies

Rooted in the LUFET concept, new emphasis is being directed into OMMIC circuit function design. By having line-unified HEMT building blocks as optical input ports, optically controlled circuits as well as optical receivers are being designed and fabricated. However, as promising as the results are, additional circuit optimization will be necessary if common problems, such as weak optical coupling and poor frequency response, are to be overcome. In the near future, introduction of multilayer structures and novel transmission lines will further enhance the OMMIC circuit performance while still reducing the overall chip area.

Furthermore, integrated optical structures in semiconductor substrates also are being designed for such functions as optical waveguiding and power division. By using chip level integration of microwave and photonic components, it is expected that photon-electron interactions will be taken advantage of in order to increase circuit flexibility. Recently a combination optical and

(Continued on page 80)

microwave MMIC probe station has been developed that allows complete circuit characterization in both the optical and electrical domains well into the mm-wave frequency range.

Three-dimensional, optically controlled MMIC-based systems will greatly enhance the capability and convenience of telecommunications equipment. Moreover, optical control in microwave components has been readily demonstrated. The challenge that lies ahead is the refinement of these technologies to provide enhanced performance as well as practicality and cost-effectiveness.

Conclusion

A shift toward the integration of lightwaves and microwaves is currently underway in the communications field. The development of these pertinent technologies becomes ever more important. Future personal communications systems will need to offer greater convenience than do current systems. ■

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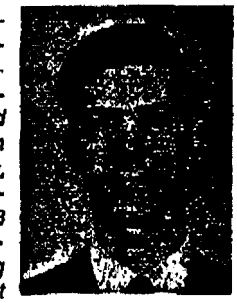

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ATTACHMENT B

Refractive Index Measurements on Single-Mode Fiber as Functions of Product Parameters, Tensile Stress and Temperature

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Introduction

Understanding effective index of refraction (EIOR) dependence on product parameter variations, tensile stress and temperature has numerous applications in the fiber and fiber-related industries. For a variety of reasons, such measurements require sample fiber lengths tens of meters or more. In order to measure the subtle influence of product variations on index, at least four decimal place accuracy is necessary.

Fiber Types Measured

Standard unshifted and dispersion-shifted, matched-clad single-mode optical fibers were measured at the nominal operating wavelengths of 1300 and 1550 nanometers. Samples were selected that represented a typical manufactured product range for delta (Δ) and mode-field diameter (MFD) parameters.

Measurement Methods

Sample lengths, L_o, were deployed in a straight line and measured between fifty-meter benchmarks surveyed to within an accuracy of two millimeters. One end of the fiber was coupled to a Fresnel reflection optical time domain reflectometer (OTDR) capable of 10-picosecond time of flight resolution, $\Delta\tau$. The associated index measurement resolution, ΔN, follows using equation (1), where c is the speed of light in vacuum (3×10^8 m/s).

$$\Delta N = (c/2L_o)\ \Delta\tau \quad . \qquad (1)$$

Evaluating (1) yields a resolution of 0.00003, which assures confidence in reporting measured index to the fourth decimal place. The initial stage of the work involved an index of refraction characterization measurement on each sample fiber in a relaxed (unstressed) condition at room temperature (22°C).

Once characterized, each sample was prepared in the same deployment setting for index versus stress measurements. Both fiber ends were epoxied to grooved aluminium blocks. The OTDR end was fixed, while tensile loads were applied in approximately 0.4-pound (20 kpsi) increments to the free end. Fiber elongations under load were measured to determine strain and correct for associated length changes in the index computations.

Refractive index as a function of temperature comprised the third stage of measurements. Characterized fiber samples were wound in loose coils and placed in a temperature chamber. Initially, index measurements were performed at room temperature to serve as controls and confirm any effect due to the coiled configuration. Measurements were taken over a temperature range of -60 to +85 degrees Celcius in 10-degree steps. Length changes, ΔL, due to thermal expansion and contraction were accounted for in the index calculations applying equation (2). The coefficient of linear expansion, α, for fused silica is $8 \times 10^{-7}/°C$ and the temperature change, ΔT, is measurement temperature minus room temperature.

$$\Delta L = L_o \alpha \Delta T \quad . \qquad (2)$$

Results

Characterization measurements over the entire sample range for delta and mode-field diameter revealed index of refraction variations in the fourth decimal place for unshifted fibers and in the third decimal place for dispersion-shifted fibers. Unshifted samples exhibited an EIOR range of 0.0006 at both 1300 and 1550 nanometer wavelengths of operation, with average values of 1.4675 and 1.4681 respectively. The dispersion-shifted EIOR

sample range was 0.0017 for both 1300 and 1550 nanometer wavelengths; corresponding average refractive indices were 1.4716 and 1.4711.

Example graphs, figures 1 and 2, of EIOR versus tensile stress for an unshifted and dispersion-shifted fiber sample show nearly linear relationships. Slopes for both fiber types were quite consistent at -0.000024/kpsi (-0.0027/% strain) across all samples measured at either wavelength. Negative slope means flight time, and therefore index, decreases with increasing tensile stress as photo-elastic theory predicts[1]. The magnitude of the slope also is close to the -0.000035/kpsi value one would obtain from a previous study on multimode fiber (P_2O_5/GeO_2 doped silica core), by Hartog, Conduit and Payne[2].

Plots shown in figures 3 and 4 are representative of EIOR versus temperature results for unshifted and dispersion-shifted fiber types. Again, all samples measured at either wavelength displayed strong consistency in the rate of change of index with temperature, 0.000012/°C. Hartog, et al also measured temperature effects on fiber index[2] obtaining data which translates to a slope of 0.000010/°C. Cohen and Fleming[3] reported 0.000010/°C as well, measuring a depressed clad single-mode fiber (with a B_2O_3 doped silica core).

References

1. Mueller, Hans. 1938. The Theory of Photoelasticity. Journal of the American Ceramic Society 21: 27-33.

2. Hartog, A.H., A.J. Conduit and D.N. Payne. 1979. Variation of Pulse Delay with Stress and Temperature in Jacketed and Unjacketed Optical Fibres. Optical and Quantum Electronics 11: 265-273.

3. Cohen, L.G. and J.W. Fleming. 1979. Effect of Temperature on Transmission in Lightguides. The Bell System Technical Journal 58: 945-951.

IOR = 1.46700 at 30° Slows propagation.
1.46721 at 70° (Longer)
[illegible] -1.8 Meter Change Per 10 Kilo 30°F

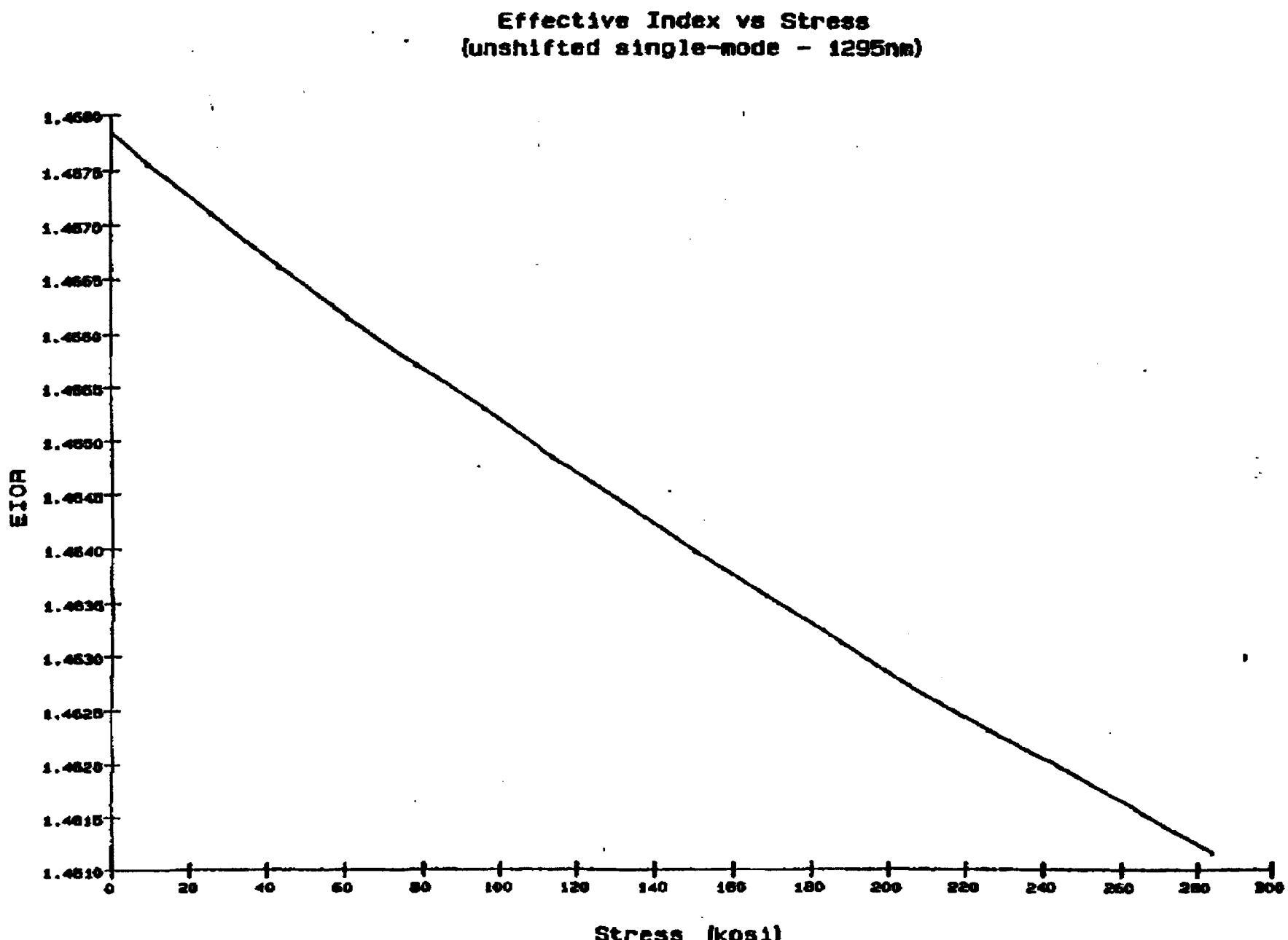
Effective Index vs Stress
(unshifted single-mode - 1295nm)
EIOR
1.4680
1.4675
1.4670
1.4665
1.4660
1.4655
1.4650
1.4645
1.4640
1.4635
1.4630
1.4625
1.4620
1.4615
1.4610
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
Stress (kpsi)

Fig. 1

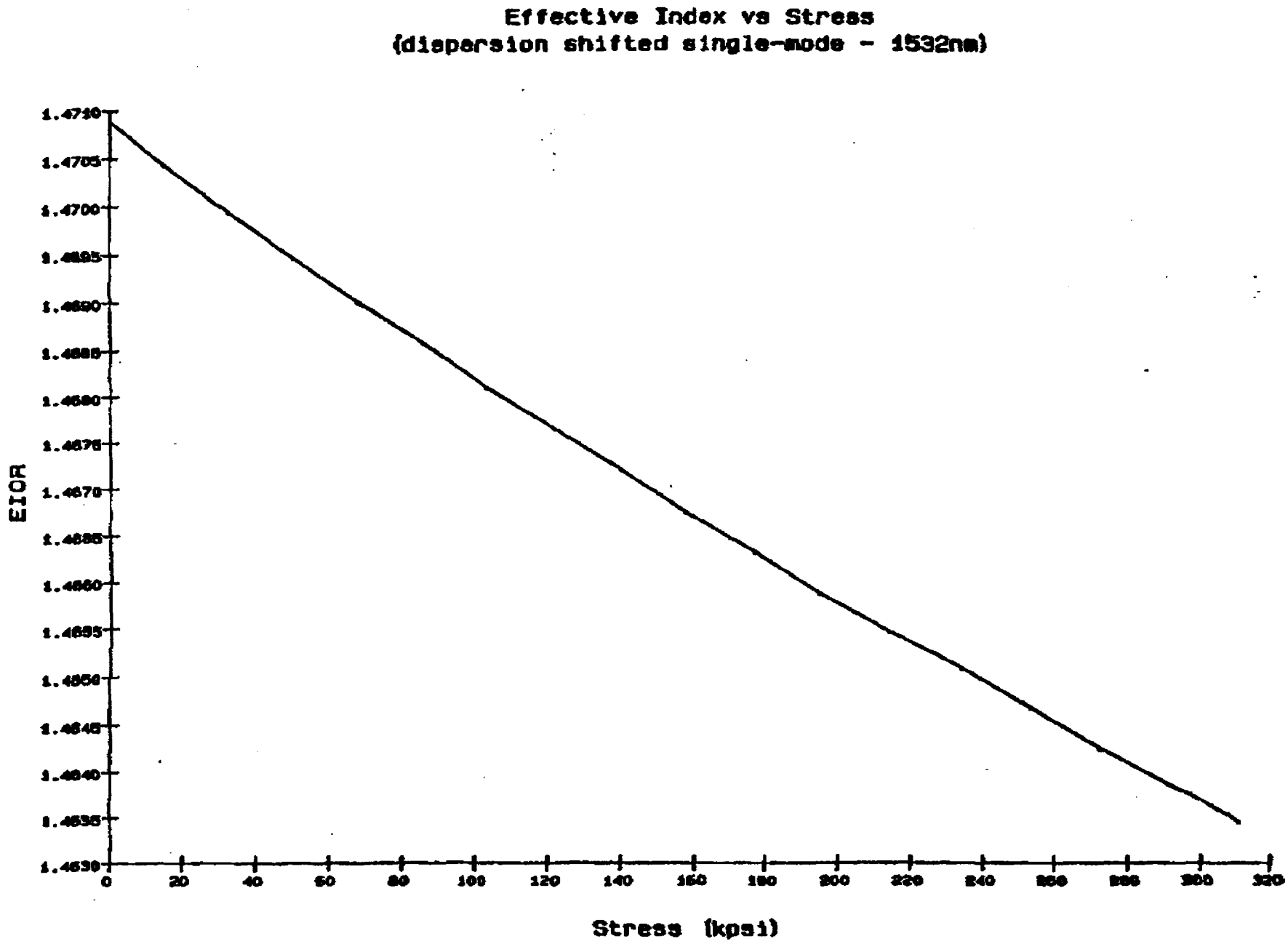
Effective Index vs Stress
(dispersion shifted single-mode - 1532nm)
EIOR
1.4710
1.4705
1.4700
1.4695
1.4690
1.4685
1.4680
1.4675
1.4670
1.4665
1.4660
1.4655
1.4650
1.4645
1.4640
1.4635
1.4630
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
Stress (kpsi)

Fig. 2

Effective Index vs Temperature
(unshifted single-mode - 1295nm)

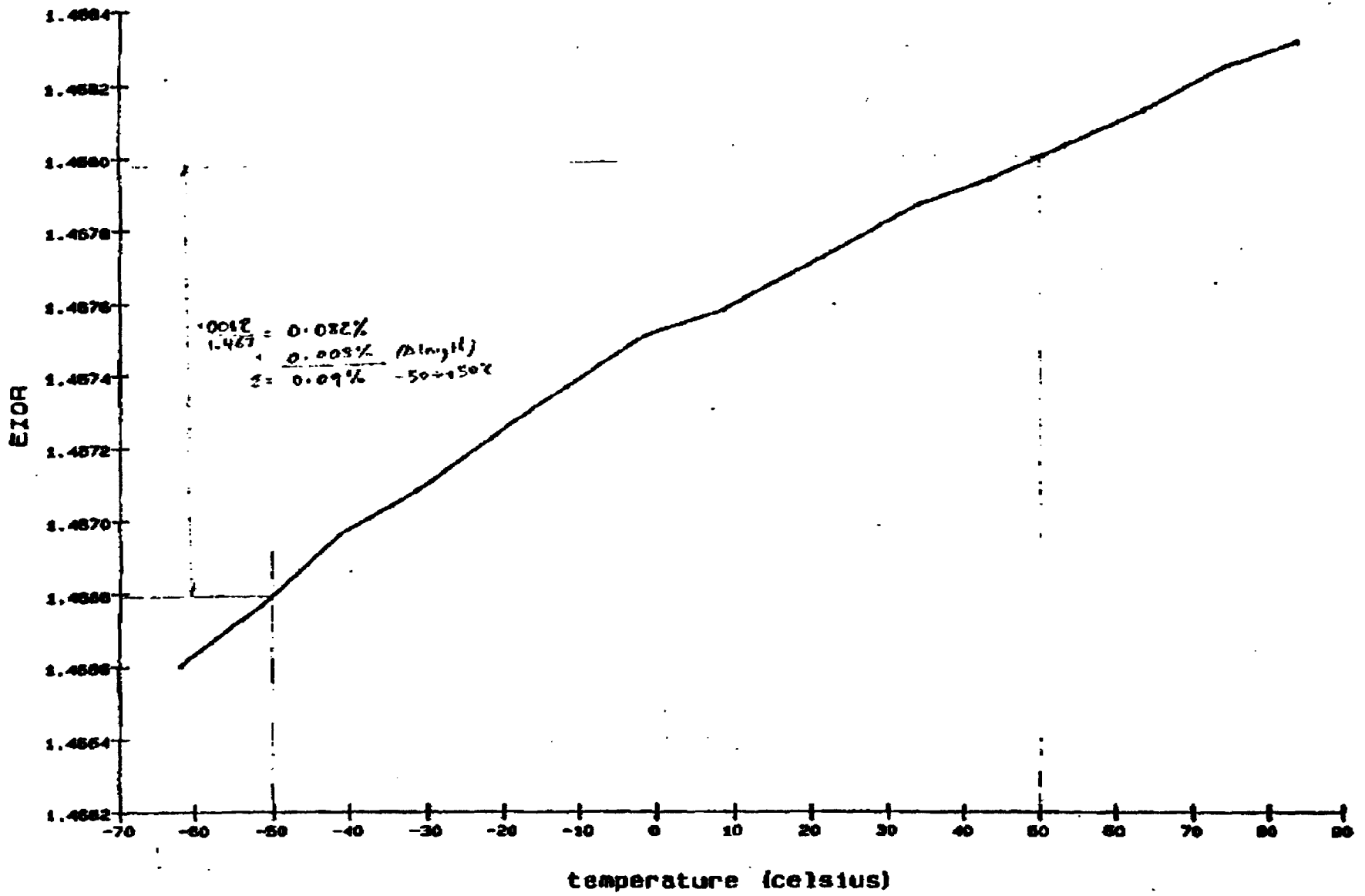

Fig. 3

Effective Index vs Temperature
(dispersion shifted single-mode - 1532nm)

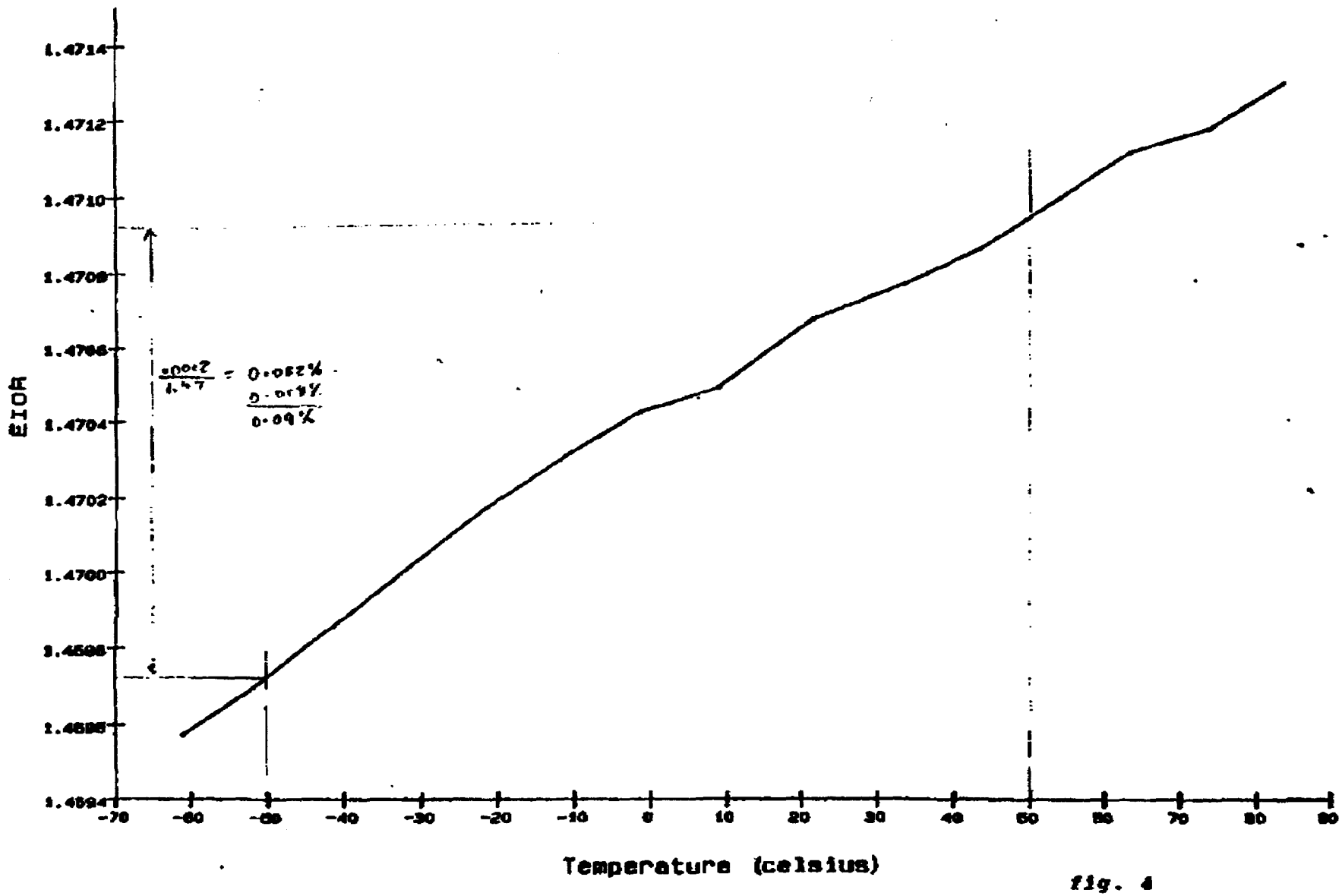

fig. 4

CERTIFICATE OF SERVICE

I, Nancy Thompson, a secretary with the Utilities Telecommunications Council, hereby certify that a copy of the foregoing comments was hand delivered, this 5th day of June, 1992, to each of the following:

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