Technical English

Unit 12
Electromagnetic Spectrum and Optical Communications

概述

- 用于通信的频谱分配情况
- 光通信相对于微波通信的优势
- 时分复用、波分复用、空分复用
- 光的粒子性对光通信的影响
- 光通信的成本问题

perusal	精读，细读
gigahertz	吉赫（10^9Hz）
impress	印，铭刻
directionality	方向性
resonator	谐振器
terahertz	特赫（10^{12}Hz）
at will	随心所欲
incur	招致，蒙受，引起
synchronous	同步的
interleave	交织
throughput	吞吐量
nonlinearity	非线性
femtosecond	毫微微秒（10^{-15} sec）
coherent	相干的
rare earth-doped	稀土元素掺杂的

obviate	避免，使成为不必要
micron	微米
miniature	小型的
miniaturization	小型化
counterpart	对等物，对等的角色
cladding	光纤包层
proximity	接近，亲近
fruition	结果实，成就
photon	光子
granular	颗粒状
bias	偏置
benign / malignant	良性的 / 恶性的
thermal	热的
myriad	无数的
swamp	沼泽，陷于沼泽，拖累

仔细研究表12.1中的频率表可以看到各种光学技术用于信息传输的不同潜力。

Various observations relating to the potential of optical technology for transmission of information can be made from perusal of the frequency line of Table 12.1.

与传输信息的光学技术潜力有关的

… 的信息传播速率通常相应于 …

The information rates in which one is interested in conventional “modern-day” communications systems generally correspond to audio rates in telephone systems, radio rates in commercial broadcast systems, or digital television rates in the most advanced video distribution systems.[1] These rates are generally below several gigahertz.

如果传输这样的信息不是将它加载到光纤上，
而是加载在略高于最大速率的射频载波上

If one were to transmit such information without impressing it on an optical carrier but instead on a radio frequency (RF) carrier a bit higher than the maximum rate, the transmission wavelength of the RF carrier would be centimeters or larger.[2] There can, however, be great advantages to using optical carriers. An obvious one is the low loss and directionality of the optical fiber.

通信系统的一个基本原则是

Clearly, the carrier must have a higher rate than the information rate. A major principle that has appeared in communications systems has been that the higher the frequency, the greater the technical complexity. Microwaves are harder to handle than are radio waves. As wavelengths decrease to approach the size of circuit components, circuit elements are no longer lumped, and leads can act as reflective components and/or antennas and lumped elements as electromagnetic resonators.[3]

随着 …，电路单元就不再是集总的，导线可起到反射元件以及（或）天线的作用，集总单元则成为电磁谐振器

因此在较高的信息率要求较高的频率这层意义上，要考虑每秒传输1比特信息的成本问题

This has generally meant that sending more information would cost more and there was therefore a cost per bit/sec (bps) of transmitted information in the sense that going to a higher information rate requires a higher frequency. Thus, the first observation from the frequency line would be that, for optical carriers, which have frequencies in the hundreds of terahertz, information bandwidth is in some sense free.

信息的带宽在某种意义上是免费的

所用技术与电和微波有根本的不同

That is to say, the optical wavelength is so small compared to most devices that the technology has changed drastically from electrical and microwave. Once we assume that we have such technology, no matter how high an information rate one might want it will not be necessary to change the carrier, as the carrier frequency is higher than any realistic information rate could become.

无论信息率有多高，再也没有必要改变载波了

Bandwidth is not completely free, though, as encoders and decoders must necessarily operate at the information rate, but much of the rest of the system must necessarily handle only the carrier plus modulation.

而系统其余部分大都只需要处理载波和调制

在这个频率，信息偏移千分之一（相应于500吉赫兹的信息率）对器件的性能将没有什么影响

If a component can handle a frequency of 5×10^{14} hertz, an information shift in that frequency of a part in a thousand (corresponding to a 500 gigahertz information rate) will have little or no effect on device performance. Therefore, once the system is already set up, one can upgrade system speed more or less at will without the kind of costs incurred by changing the electromagnetic carrier in conventional systems.

大体上就可以随意升级系统而不会涉及常规系统中改变电磁载波所需付出的那种代价

A consequence of the size of the optical bandwidth is that the optical carrier can be used to carry many different telephone conversations, television programs, etc., simultaneously. The process by which this is generally carried out (at least in synchronous format) is called time division multiplexing (TDM).

通常实现这种同时传输多路信息的过程（至少以同步格式实现）称为时分复用

The idea is that, if one wishes to multiplex 16 different channels each transmitting at 1 Mbps, one could perform this by dividing each bit period by 16 and then interleaving the bits into a composite 1μsec bit (1 Mbps rate) which actually carries 16 bits of information on it.[4]

将每一比特所占时间除以16，然后将16个数据比特交织成一个持续1微秒的复合比特（即比特率为1 Mbps），这一复合比特实际上带有16比特的信息

使实现TDM有了极大的可能

With telephone conversations representing a rate of 64 kbps, the Tbps bandwidth of the optical carrier holds great promise for TDM. Of course, TDM is not the only multiplexing scheme one can imagine using. One could imagine impressing a number of subcarriers, spaced by perhaps some gigahertz, onto the optical carrier.

也许相隔几个吉赫兹

在输出端按其不同的载波波长来重新分割

被调制到信息的频率

Each of these carriers could then be modulated at an information rate and then reseparated according to their different carrier wavelengths at the output. Such a scheme is referred to as wavelength-division multiplexing (WDM) or subcarrier modulation, depending on the implementation. Many of the present-day schemes for increasing link throughput with increasing traffic involve combining many TDM signals onto WDM carriers.

涉及到将许多TDM信号放入WDM载波中去

In fact, the limitation on density of WDM turns out to be not bandwidth but power. That is, each channel requires some amount of power. The more channels, then, the higher the power requirement. At some power level, optical fiber nonlinearity becomes important, and this nonlinearity tends to mix the signals together. There is presently much effort going on in trying to find ways to equalize such nonlinearities.

目前正在进行大量的研究，努力寻求对这种非线性的均衡处理。

当它通过光速与光的波长相联系时尤其如此

The high carrier frequency of the optical carrier also has drawbacks, especially as it relates, through the speed of light, to the optical wavelength. The optical period corresponds to less than two femtoseconds. This means that phase control corresponds to manipulation of sub-femtosecond periods of time. Although techniques to do such are emerging, they are complicated — much more complicated than manipulating microwave or radio frequency waveforms.

毫微微秒（10^{-15}秒）

For this reason, coherent optical reception is still a laboratory technology. Development of the rare earth-doped optical fiber amplifier seems to have obviated the need for coherent techniques in telecommunication as far as improved signal-to-noise ratio goes.

随着信噪比的提高，看来稀土金属掺杂光纤放大器的发展使通信系统中不再需要用相干技术。

微米

The short period of the optical wave also implies a short wavelength centered around half of a micron. The smallness of the optical wavelength, therefore, allows for the miniaturization of transmit and receive modules, which should allow considerable reduction in size, weight, and cost of optical communication systems with respect to microwave/radio wave counterparts.[5]

使光通信系统的尺寸、重量以至价格相对于微波、无线电波通信系统都大为降低

封装密度愈高，窜音就愈严重

In the case of microwaves, the higher the packaging density of open microwave channels, the worse the crosstalk. No matter how tightly one packs fiber, on the other hand, the crosstalk is essentially zero if the cladding is properly designed. This leads to the characteristic that fiber is an excellent medium for space division multiplexing (SDM) — that is, packaging a number of channels with different information streams in close proximity.

将多个传输不同信息流的信道紧密地封装在一起

还有待于落实在具体成果中

Although all the advantages of coherent optical communication systems have yet to be brought to fruition, another property of optical radiation has made today's optical communication systems not desirable for applications.[6] The important property here is that of photon energy. As is seen from Table 12.1, the photon energy ranges from roughly 2 eV to roughly 4 eV.

光辐射的另一性质却使目前的光通信系统不利于应用

具有这样的光子能量需要付出高昂的代价

This would seem to be an advantage in efficiency. However, there is a penalty to be paid for having such photon energy. Because single photons are detectable, the emission/reception process must take on a granular nature. As is well-known, even in a steady rain, the probability of a raindrop landing (as a function of time) follows a Poisson distribution, implying that there is raindrop bunching.[7]

雨滴落地的概率（作为时间的函数）服从Poisson分布，这意味着有成串的雨滴

即使在恒定偏置电流条件下激光也发出光子束

A raindrop would rather fall right after the one before. Raindrops are impatient and don't like to wait. In much the same manner, a laser likes to spit bunches of photons even under constant bias current. Such behavior leads to a type of noise commonly referred to as shot noise or quantum noise. On the emission/detection process, this turns out to be quite serious for analog communications although much more benign in the digital case.

在发射/检测过程中，这一问题对于模拟通信变得相当严重，尽管在数字通信中要轻微得多

热声子的平均能量大约是波尔兹曼常数*k*乘以温度*T*

As was mentioned above, the average energy of a thermal phonon is roughly Boltzmann's constant *k* times the temperature *T*, which for room temperature is roughly 1/40 of an eV. Optical quantum detectors can operate at room temperature, as single photons are measurable. Therefore, optical direct detection can be quite sensitive if shot noise-limited.

如果散粒噪声受到限制，光的直接检测会十分灵敏

Direct detection, further, is totally compatible with intensity modulation schemes — schemes in which the source is essentially just turned on and off.[8] Such modulation schemes are the easiest to implement.

另外，直接检测与强度调制方案完全兼容，在这些方案中电源实质上只是简单地接通或断开。

用直接检测方案可实现在许多领域具有竞争力的小巧的宽带系统

When coupled with light's short wavelength which allows for miniature sources and detectors and micron-sized waveguides, direct detection schemes have allowed for small, lightweight, high bandwidth systems which are competitive in many areas, most notably to the present telecommunications transmission, although a myriad of other applications are continually opening up.[9]

尽管无数应用正在不断涌现出来

这些应用比预料的出现得慢

As mentioned previously, these applications have tended to open up more slowly than originally predicted, as cost was really not much of a consideration in telecommunications, where equipment costs are swamped by other considerations.[10] With consumer electronics, one need not worry about right of way or installation.

（线路）成本并非电信系统中真正重要的考虑因素，通信设备的成本主要受到其他因素的制约

用光技术将相距几米的个人计算机连接起来

At present, the cost of connecting to personal computers a few meters from each other optically is so expensive that fiber has not yet come to the consumer market. The high cost of the link in such a case, though, is not fundamental but more historical. Present-day developments in millimeter core plastic is an example of a much cheaper technology than, for example, glass fiber. The costs of components to go into fiber links as well as packaging costs are presently being reduced and new applications are opening up.

结合课文的思考题

- **What are the advantages of optical communications over microwaves?**
- **Why is the information band virtually free of charge in optical communication systems?**
- **What is shot noise or quantum noise?**
- **What prevents optical fibers to enter the consumer market?**

Exercises

- **Orthogonal Frequency Division Multiplexing (OFDM) is a multicarrier transmission technique, which divides the available spectrum into many carriers, each one being modulated by a low rate data stream. OFDM is similar to FDMA in that the multiple user access is achieved by subdividing the available bandwidth into multiple channels, which are then allocated to users.**

  正交频分复用（**OFDM**）是一种多载波传输技术，它将可用频谱分成许多载波，每个载波被一个低速率数据流调制。**OFDM**与**FDMA**相似，多用户接入是通过将可用频带分成多个信道分配给用户来实现的。

Exercises

- **However, OFDM uses the spectrum much more efficiently by spacing the channels much closer together. This is achieved by making all the carriers orthogonal to one another, preventing interference between the closely spaced carriers.**

  然而OFDM中各载波之间的间隔要小得多，使得频谱利用率大大提高。这是通过使各载波之间相互正交来实现的，这样可避免紧密相接的载波之间的相互干扰。

Exercises

- **Coded Orthogonal Frequency Division Multiplexing (COFDM) is the same as OFDM except that forward error correction is applied to the signal before transmission. This is to overcome errors in the transmission due to lost carriers from frequency selective fading, channel noise and other propagation effects.**

  编码正交频分复用（COFDM）和OFDM一样，只是在传输之前进行前向纠错编码。这是为了克服由选频衰落、信道噪声和其他传播效应导致载波丢失而引起的传输差错。

Exercises

- **For this discussion the terms OFDM and COFDM are used interchangeably, as the main focus of this thesis is on OFDM, but it is assumed that any practical system will use forward error correction, thus would be COFDM.**

  在本文的讨论中对OFDM和COFDM两个术语不加区别，但假定任何实际系统都将使用前向纠错，因而都是COFDM。

Exercises

- **In FDMA each user is typically allocated a single channel, which is used to transmit all the user information. The bandwidth of each channel is typically 10kHz-30kHz for voice communications. However, the minimum required bandwidth for speech is only 3kHz. The allocated bandwidth is made wider than the minimum amount required to prevent channels from interfering with one another.**

  在典型的FDMA中，每个用户分配到一个信道用于传输所有的用户信息。每个信道的典型带宽是用于语音通信的10 kHz～30kHz。然而语音要求的最小带宽只要3kHz。分配的带宽大于最低要求的带宽以防止信道之间的干扰。

Exercises

- **This extra bandwidth is to allow for signals from neighboring channels to be filtered out, and to allow for any drift in the center frequency of the transmitter or receiver. In a typical system up to 50% of the total spectrum is wasted due to the extra spacing between channels. This problem becomes worse as the channel bandwidth becomes narrower, and the frequency band increases.**

  多余的带宽是为了能将相邻信道的信号过滤掉，并能容忍发射机和接收机中心频率的漂移。在一个典型的系统中，由于信道间多余的间隔使高达50%的总频谱被浪费掉。当信道带宽变窄而总频带增大时情况更加严重。

Exercises

- **While the exact form of this prior knowledge is problem dependent, a KB system consists of a knowledge base containing information specific to a problem domain and an inference engine that employs reasoning to yield decisions.**
- 由于先验知识的确切形式是依赖于问题的，一个基于知识的系统是由一个面向特定问题域信息的知识库和一个能够进行推理找到解决方法的推理引擎构成的。

While: 不是“…的时候”

employ: 不能硬译为“雇佣”

yield: 不能硬译为“产出”

不是“问题所在”，“关联问题”，“问题的依赖性”