LASER SATELLITE COMMUNICATION

INTRODUCTION

a)Transmission at frequencies in 10^{14}

b)Advantage

- Greater bandwidth
- Smaller beam divergence angles
- Smaller antennas

c)Modes of communication

- Aerial
- Fiber optical communication
- Optical computer

ARIEL

- Ariel :data and images are transferred using low power beams
- Impossible to jam by known means
- Weather dependent
- Clear day – several miles
- Rain ,fog ,mist -- limited to shorter distance

Fiber optical communication& optical computers

- Guided media
- 4 Giga bits of information/sec over a span of 120Km

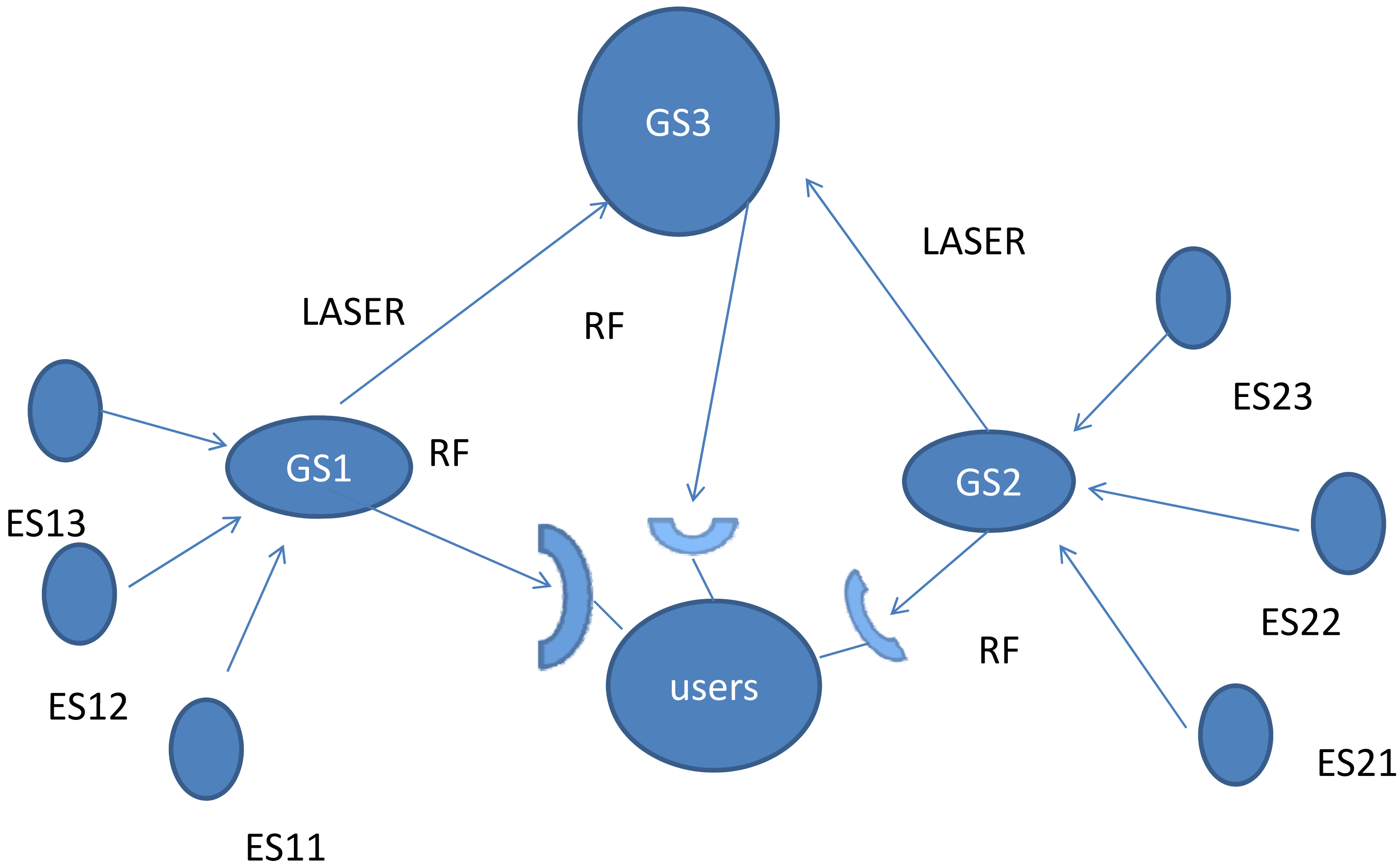
Optical computers

I. Light is used instead of electrical circuit
II. Light can be encoded with much more information
III. Zero resistance to flow ,more information than the equivalent sized electric circuit
IV. Optical signal can be used in parallel

Use

- Communication between the satellite themselves
- Can not be used between earth station and geostationary satellite being atmospheric dependent

LASER SATELLITE COMMUNICATION



GSS =GEAOSTATIONARY SATELLITE
ESS= EARTH OBSERVATION SATELLITE

LINK ANALYSIS

Atmospheric Effects:

- Attenuation due to energy absorption
- Beam spreading due to scattering of light waves
- Beam bending due to refocusing of optical beams
- Beam break up due to loss of coherence

ATMOSPHERIC

- Dependent on wavelength
- Dependent on elevation angle

Complete link design

- Up link and downlink RF is used to satellite
- Two satellite cross link (optical link)
- RF up link wave form

$$s(t) = u(t) + n_u(t)$$

$$u(t) = uplink\ .carrier$$

$$n_u(t) = uplink\ .Noise\ .and\ .Interferen\ ce$$

$$P(t) = P_r(1+\beta s(t))$$

P_r *isaveragep owerand* β*i* sin *tensity* mod *ulation* $\beta \leq 1$

The reciever satellite the signal of optical reciever by photo detecting it the photo detector detects the intensity modulated signal as

$$R\left[\beta P_r s(t)\right] = R\beta P_r\left[u(t) + n_u(t)\right]$$

$R =$ *photo* detector responsiti vity

$\mathrm{P_s}$ = *satellite* – *downlinkpo wer*

$$P_s = \alpha_s^{\,2} P_t[(R\beta P_r)^2 P_{cu}]l$$

$$Pns = \alpha_n^{\,2} P_t[(R\beta P_r)^2 P_{nu} + P_{PD})]L$$

α is signal and noise suppression Pns =total downlink retransmitted noise power
L is the downlink losses
Pcu is the uplinkpower ofu(t)
Ppd is photo detector noise
Pnu additional noise by the down link

$$(C/N)_T = \frac{P_s}{P_{ns} + P_{nd}}$$

$$(C/N)_u = \frac{P_{cu}}{P_{nu}}$$

$$(C/N)_{op} \approx \frac{P_s}{P_{PD}}$$

$$(C/N)_r \approx \frac{LP_t \alpha^2}{P_{nd}}$$

$$\alpha_s^2 = \left[1 + \left(\frac{1}{C./N}\right)_{op}\right]^{-1}$$

$$(C/N)_T = \left[(C/N)_u^{-1} + (C/N)_{op}^{-1} + (C/N)_r^{-1}\right]$$

Satellite beam and acquisition, tracking and pointing

- Beam is narrow
- Pointing problem
- Pointing within the pointing error$\pm\theta_c$ radians
- Optical beacon(unmodulated light source)
- Transmitter satellite receives the beacon from the receiving satellite
- Transmits its modulated laser beam back to the receiving satellite
- Angle of drifting of the receiving satellite(point ahead angle)

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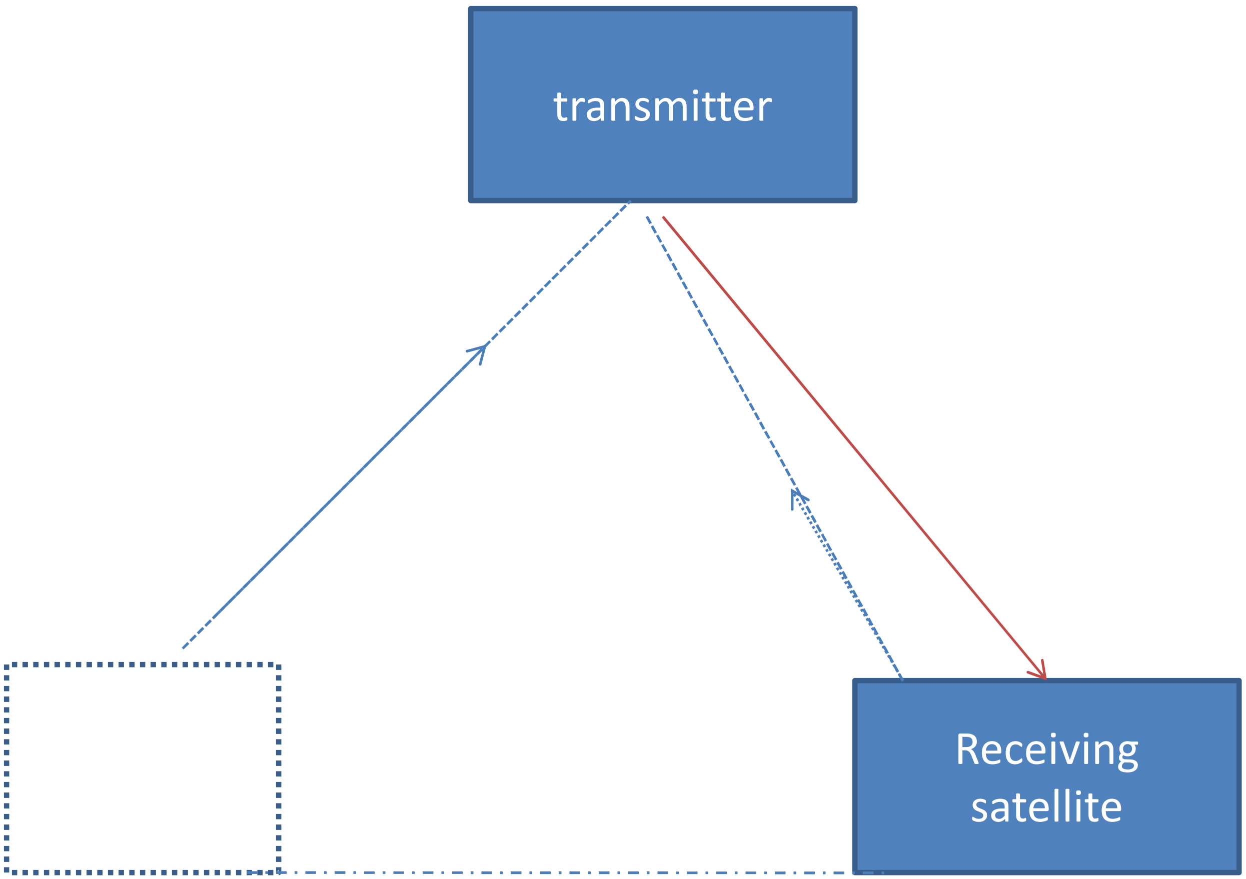
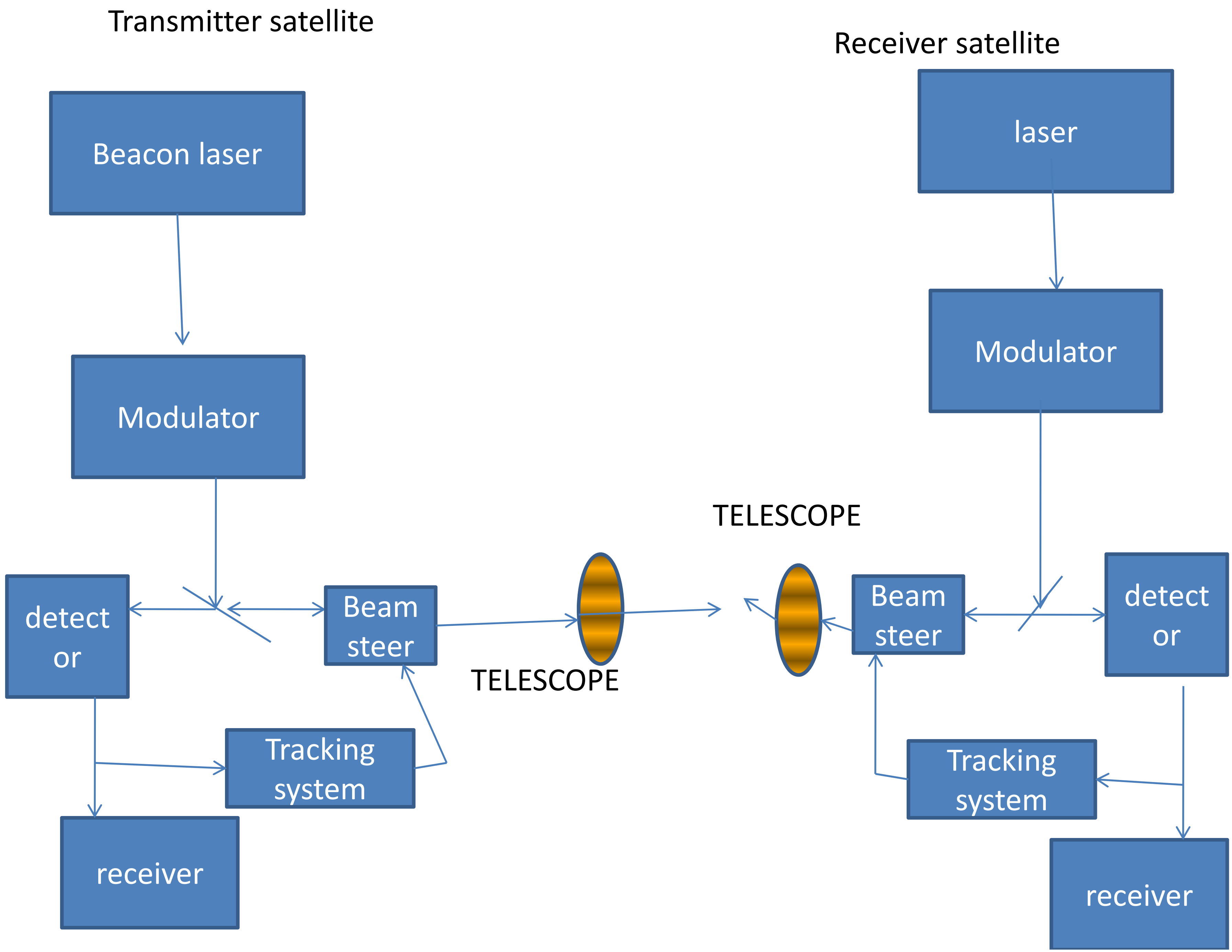

transmitter
Receiving satellite

Satellite beam and acquisition, tracking and pointing

- Vt is the tangential velocity of the receiving satellite
- α= Vt/150 micro radians
- Point ahead angle exceed the one half of the laser modulated beam width then the use of point ahead angle is made


Transmitter satellite
Beacon laser
Modulator
detect
or
Beam
steer
Tracking
system
receiver
TELESCOPE
TELESCOPE
Receiver satellite
laser
Modulator
Beam
steer
detect
or
Tracking
system
receiver

OPTICAL SATELLITE LINK TRANSMITTER

- LASER SOURCE
- MODULATOR
- ANTENNAS

LASER

- LASER SOURCE:

a. GAS LASER,
b. SOLID STATE LASER,
c. SEMICONDUCTOR LASER

Semiconductor laser

- AlGaAs and InGaAsP are also being used
- AlGaAs is reliable between 0.78 and 0.86 µm
- InGaAsP emits between 1.2 and 1,65 µm
- Lasers are low powered devices
- Used in arrays to increase output

LASER
Advantage

- Small size
- Weight
- High efficiency
- Reliability
- Easily modulated

DISADVANTAGE

- Beam combining problem
- Integrated optical technology has developed coherent combining technology
- Increasing the power
- Decreasing the beam divergence

Laser commonly used in satellite communication

LASER TYPE	WAVELENGTH	AVERAGE POWER OUTPUT	EFFICIENCY	CHARACTERISTICS
Nd-YAG	1.06 µ	0.5-1 W	0.5-1%	Requires elaborate modulation equipment, diode or solar pumping 10,000 life hours
Crystal	0.532µ	100MW	0.5-1%	
GaAs	0.8-0.9µ	40MW	5-10%	Life hours 5000 ,reliable, small, rugged, compact, directly and easily modulated Easily combined into arrays Nano second pulsing

Laser commonly used in satellite communication

LASER TYPE	WAVELENGTH	AVERAGE POWER OUTPUT	EFFICIENCY	CHARACTERISTICS
CO_2(gas laser)	1.06 µ	1-2W	10-15%	Life hours 20,000 used in IR range, detectors are poor, Uses a discharge tube, modulation is difficult
HeNe (Helium –Neon)	0.63µ	10MW	1%	Life hours 50,000.requires external modulation, has gas tube ,is power limited and is inefficient

MODULATORS

- Direct intensity modulation
- Driving current is varied in accordance with the type of modulation

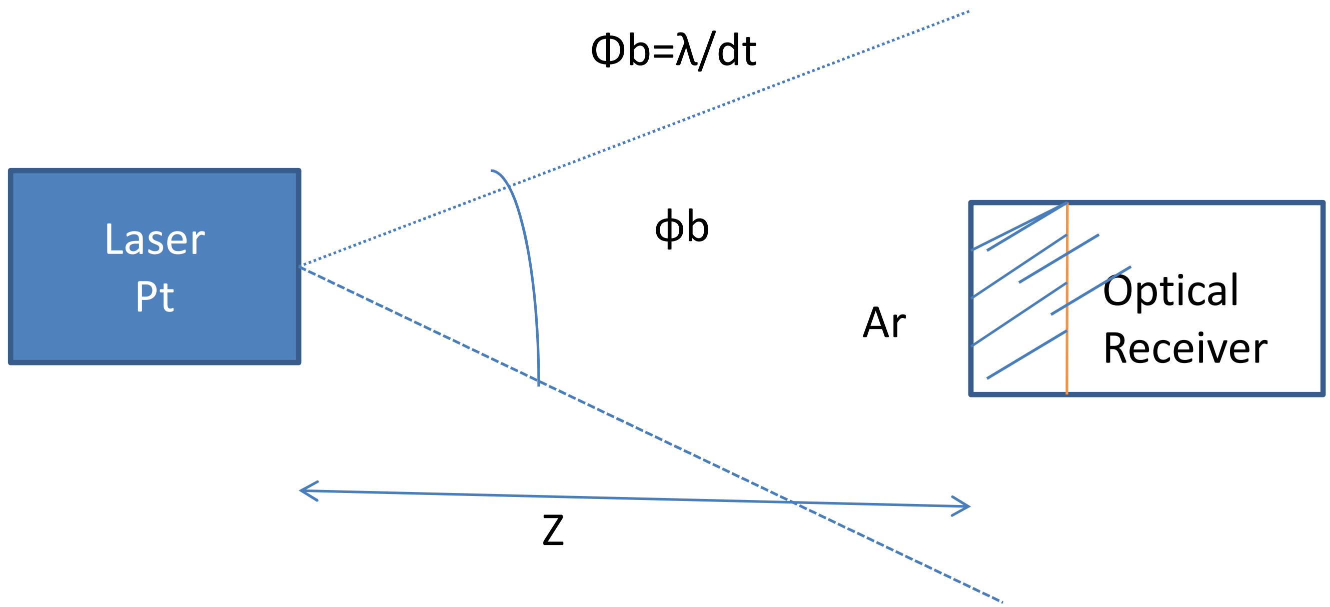
Various optical laser modulation method

Modulation type	Analog	pulse	digital
Information Signal	Time Continuous	Time Continuous Or sampled	Time sampling
Carrier Parameter	Continuous	Continuous Or Quantized	Quantized or coded
Example	Intensity modulation	Pulse intensity modulation	Pulse code modulation, intensity modulation

ANTENNA

- Conventional Telescopes
- Size and geometry – as per the wavelength and geometry
- Narrow light beams
- Lensing system for transmission and focusing

Optical Antenna Transmission



$$P_r = \frac{P_t A_r}{\phi_b^2 z^2}$$

$$g_t = \frac{4\pi}{\phi_b^2}$$

$$L_p \approx \left(4\pi / \lambda z^2\right)$$

$$P_r = \frac{P_t \left(d_t d_r\right)^2}{\lambda^2 z^2}$$

$$n_r = \frac{P_r}{hf_o}$$

fo is optical frequency
Nr photo electrons per second

Optical satellite link reciever

- telescope: focus the optical signal on to the photo detector
- Optical filter: eliminate back ground radiation that is not of same wavelength as the optical signal

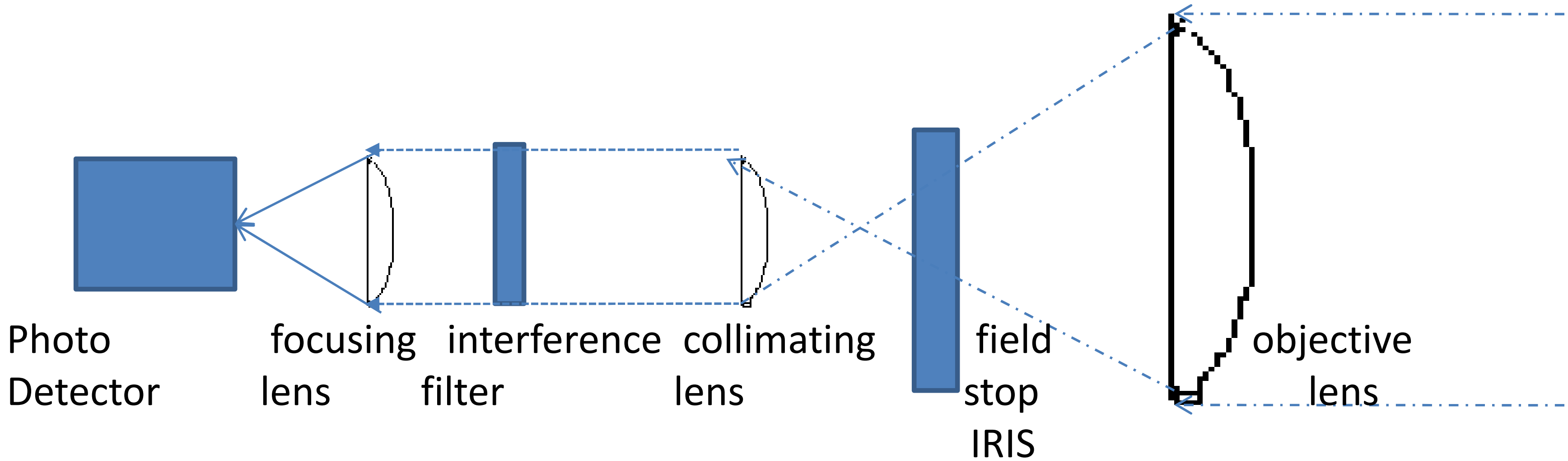
$$\frac{\Delta \lambda}{\lambda_0} \approx \frac{B_o}{f_0}$$

Optical detection

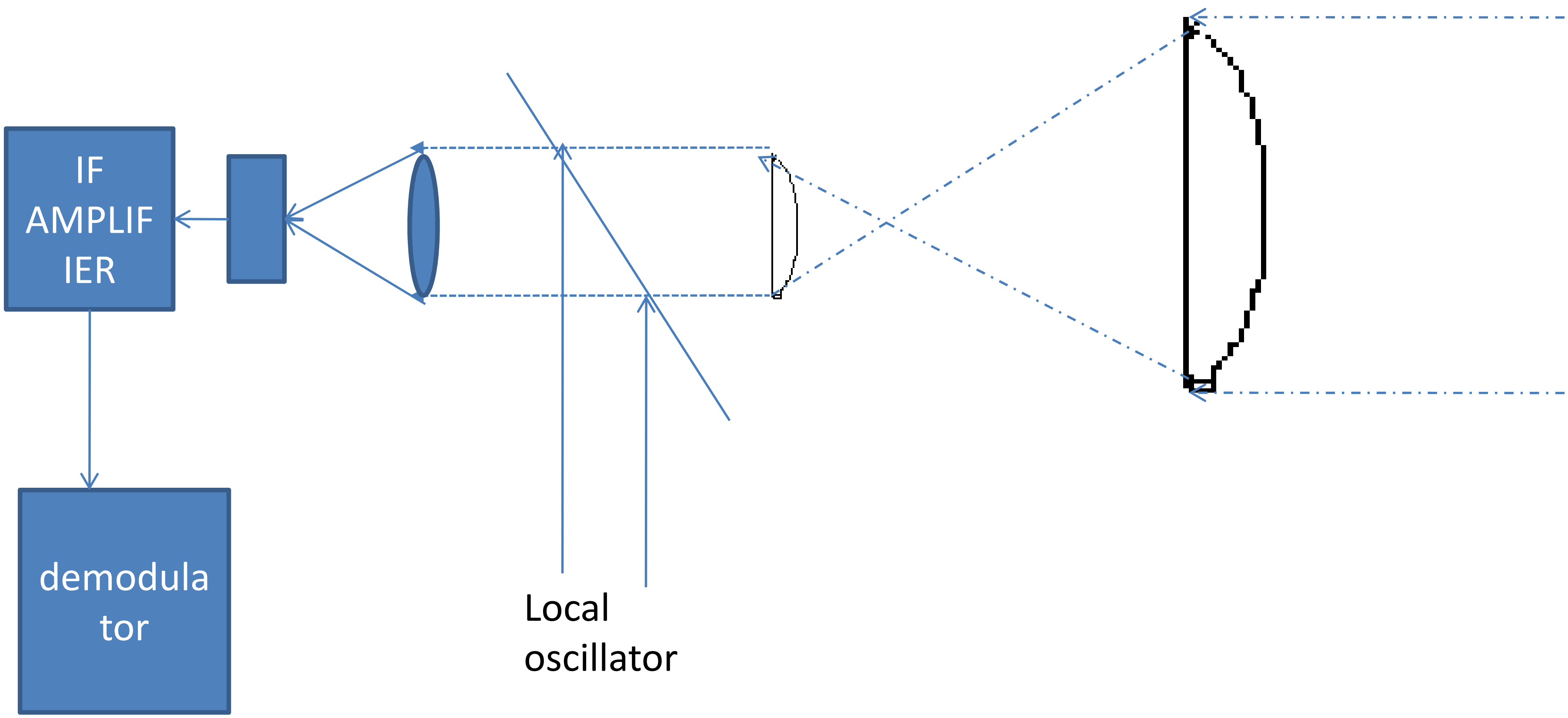
- Direct detection System
- Heterodyne system

Direct Detection System

- Respond to the signal intensity



Principle of heterodyne detection



Heterodyne receiver

- Optical receiver field view:

Field arriving angles over which lenses will focus the impinging field onto the photo detector surface

Detector area and focal length

$\Omega fv = Ad/f^2c = Ad/Ar = (Ad/\lambda^2)(\lambda^2/Ar)$

(λ^2/Ar) diffraction limited field of view

Heterodyne receiver

- P-i-n diode and avalanche photo diode
- Detection efficiency, gain, responsivity and bandwidth
- Wave length dependent, material used for photo emission
- Detected count rate of optical receiver

$N_s=(\eta/hf_o)P_r$

Photo detector

- Gain is increased by cascading photo emmissive surface– noise increases
- Excess noise $F= 1+\sigma^2_d/(\bar{G})^2$
- $\bar{G}$ mean gain
- σ^2_d gain variance
- Responsivity : current produced for a given output
- $R=e\eta \bar{G} /hf_o$

Photo detector noise model

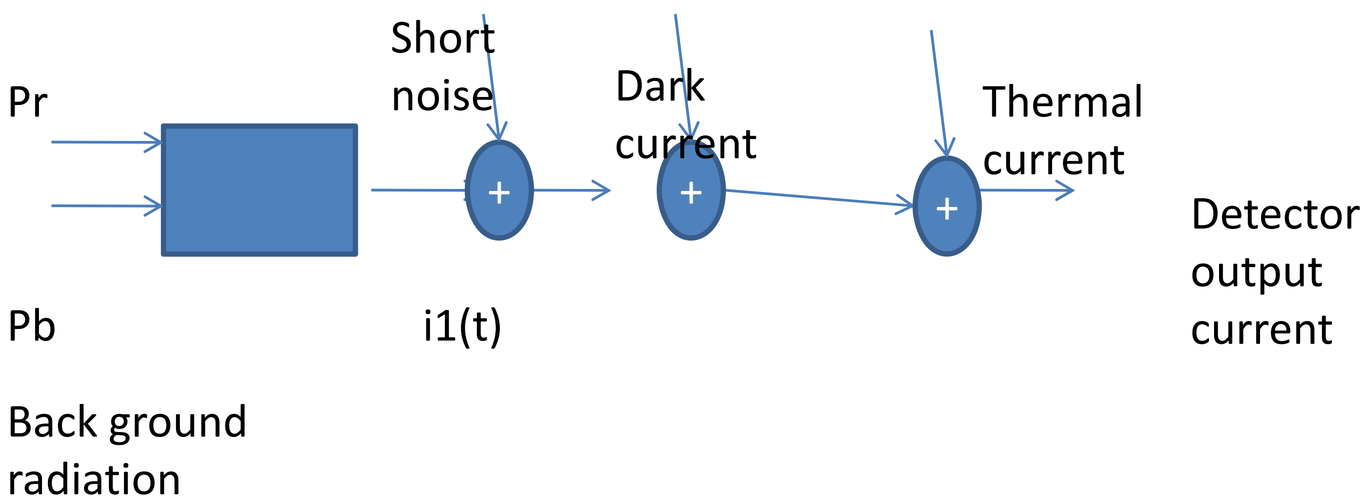


Photo detector

- $Ns(w)=\overline{G^2}\,FeR\overline{P}$
- $Ndc(w)=eI_{dc}$
- $Nt(w)= 4KT^{o}_{eq}/R_L$
- R_L is impedance load
- T^{o}_{eq} noise equivalent temperature
- Intensity modulation so s(t) information wave form modulated on the laser field
- $Pr(t)= Pr[1+\beta s(t)]$

Photo detector

- After detection photo detector current will be
- $i(t)=R[Pr(t)+Pb]+i_{sn}(t)+i_{dc}(t)+i_{i}(t)$
- $Ps=(RPr\beta)^2$ signal power
- $Pn=N_0\ (2Bm)$ total noise power
- $SNR=Ps/Pn$
- $=(RPr\beta)^2 /[\ G^2 \bar{F}eR(Pr+Pb)+ eI_{dc}+ 2KT^o{}_{eq}/R_L]2Bm$