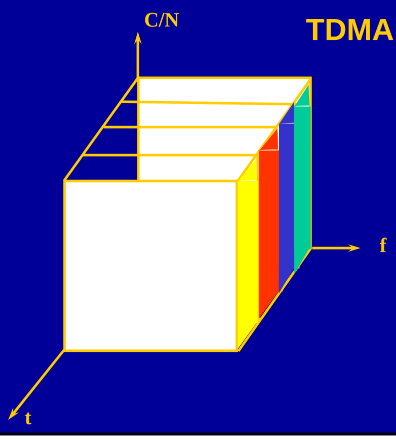
TDMA

CAPACITY

- assigned in time slots
- during this period access to full available bandwidth at given C/N
- synchronization required

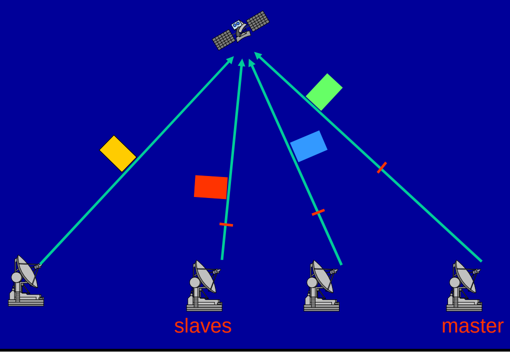
TDMA



SINGLE-CARRIER OPERATION

- at any given time: only one carrier transmitting
- no intermodulation with other carriers
- transponder can be driven more closer into saturation
- better power efficiency

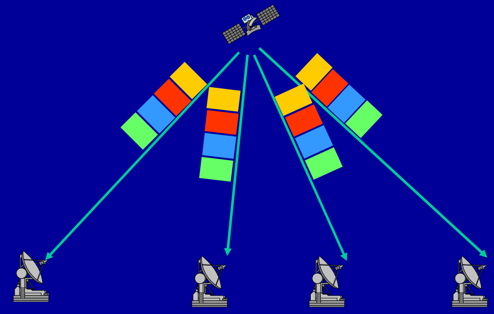
BURST TRANSMISSION



BURST TRANSMISSION

- bursts must arrive at transponder in sequence
- no overlap (otherwise corrupted packets)
- stringent timing synchronization requirements

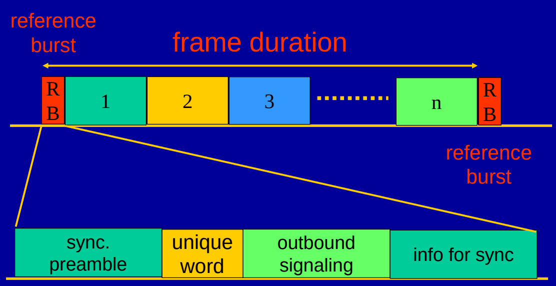
BURST RECEPTION



SYNCHRONIZATION

- one station acts as the synchronizing master
- transmits at regular intervals a reference burst
- reference burst used to synchronize all stations
- frame structure

FRAME STRUCTURE



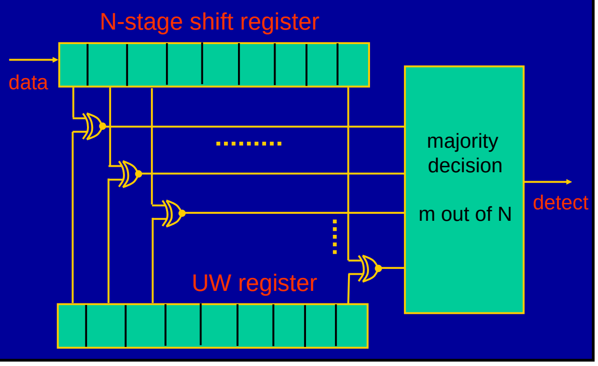
SYNC. PREAMBLE

- Demodulators require certain time to lock on frequency, timing and phase
- sync preamble is a (usually pseudo-random) pattern which assists in synchronization
- 010101… produces discrete spectral lines!
- 40…160 symbols

UNIQUE WORD

- Bit pattern which has a low probability of occurrence in data
- 32, 64, 128 bits long
- correlator used to detect UW

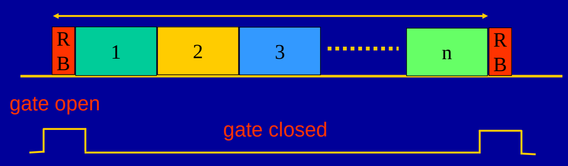
CORRELATOR



DETECTION THRESHOLD

- Allowable errors in UW:
  - D= N-m = 0,1,2,3,…
  - if D=0: comparator, all bits must match
  - if D>0: correlator
- if D too large: risk of false detection
- compromise to set threshold that it works in case of errors without unacceptable probability of false detection

WINDOW TECHNIQUE



PROCEDURE

- Open window
- wait for UW
- once detected, close detection gate
- open detection gate shortly before end of frame
- wait for UW
- if 3 times in a row correct -> start operations

UNIQUE WORD

- one UW for master station
- different UW for the slave to distinguish between master and slave bursts

PERFORMANCE OF DETECTOR

- probability of non-detection
- probability of false detection (traffic pattern or even random noise detected as UW)

NON-DETECTION

- Probability decreases, if
  - bit error rate of link decreases
  - length of UW decreases
  - correlation threshold decreases

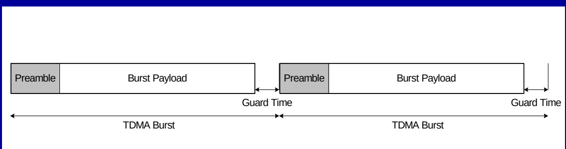
FALSE DETECTION

- decreases, when
  - length of UW increases
  - correlation threshold increases

SYNCHRONIZATION

- between all stations needed
- avoiding mutual interference
- no proper detection possible if bursts overlap

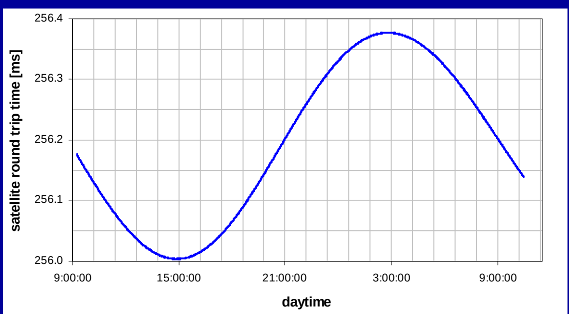
Burst Format



ORBIT CONTROL

- problem: constellation earth station - satellite is not constant!!
- satellite stays in “box” typically 0.1 deg.
- satellite moves in box 75 x 75 x 35 km
- altitude variation of 35 km within 24 hours

Round-trip time variation of a geostationary satellite



EFFECTS

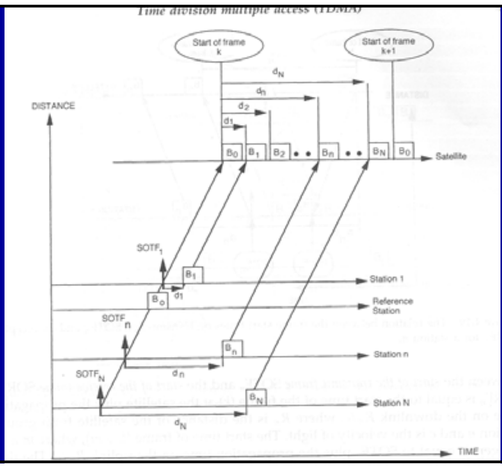
- Variation in round-trip time of approx. 250 µs (frame duration 2…32 ms)
- Doppler effect: displacement velocity of 10 km/h
  - displacement of burst in frame 20 ns/s
  - guard time between bursts 1 µs:
    $1/2.10^{-6}/20.10^{-9} = 25$ s before corrective measure needs to be taken

TRANSMISSION & RECEPTION

- Any station must transmit its burst such that it arrives at the satellite with delay d_n with respect to reference burst
- d_n is specific to each station
- set of d_n determines arrangement of bursts in frame: *burst time plan*

START OF TRANSMIT FRAME

- $SOTF_n$
- time in which station would have to transmit in order to position its burst in time slot occupied by the reference burst
- problem of synchronization: determination of SOTF



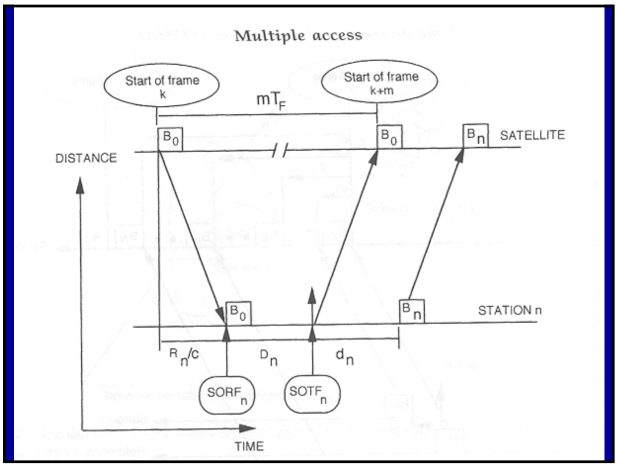
BURST TRANSMISSION

- Once instant is known:

  station n has to transmit its traffic burst with delay d_n with respect to $SOTF_n$

START OF RECEIVE FRAME

- $SORF_n$
- instant of detection of UW
- equal to start time of frame k at satellite plus propagation time on downlink R_n/c (R_n…distance to satellite)



FRAME (k+m)

- m…integer
- equal SOTFn + propagation time on downlink R_n/c
- time separating start of frame (k) and frame (k+m) at satellite: mT_F
- $SOTF_n - SORF_n = D_n = mT_F - 2R_n/c$

REQUIREMENT

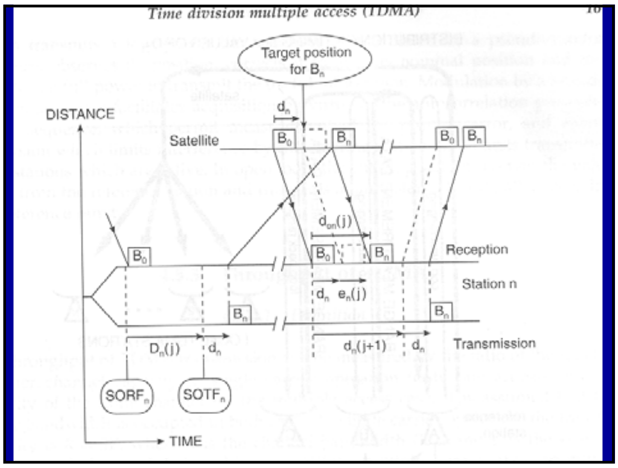
- For D_N to be positive:
- chose m such that mT_F is greater than R_n/c for station which is furthest from satellite
- example: TELECOM 1 system m = 14, T_F = 20 ms, max. roundtrip: 280 ms

SUMMARY

- Station n identifies $SORF_n$ by detection UW of reference burst
- transmits its traffic burst $D_n + d_n$ later
- d_n determined by burst plan
- Problem: find exact D_n

CLOSED LOOP TIMING SYNCHRONIZATION

- Position in frame determined by measuring time between reception of reference UW and its own traffic UW
- $d_{on}(j)$ value observed on reception of frame for which $D_n(j)$ was determined



BURST POSITION ERROR

- $e_n(j) = d_{on}(j) - d_n$
- station changes D_n: $D_n(j+1) = D_n(j) - e_n(j)$
- minimum time required to make corrections: roundtrip time (max. 280 ms)

Alternative Method

- Master station measures $e_n(j)$ of each slave
- Distributes error back to slaves
- Must be used, if a station cannot receive its own bursts

OPEN LOOP SYNCHRONIZATION

- knowledge of satellite position
  - data from satellite operator (tracking)
  - triangulation by 2 auxiliary ground stations
- calculation of distance to each ground station
- distribution of offset values by reference (master) station

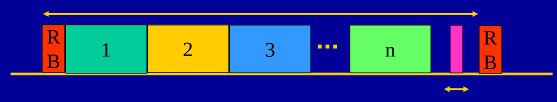
ACQUISITION OF SYNCHRONISATION

- each time a station wishes to enter network
- station transmits burst in a dedicated slot (first access slot FAS)
- Station observes position of burst
- determines error
- corrects error

ACQUISITION OF SYNCHRONISATION

- correctly positioned

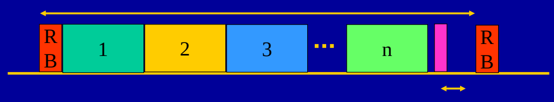
frame duration



ACQUISITION OF SYNCHRONISATION

- early

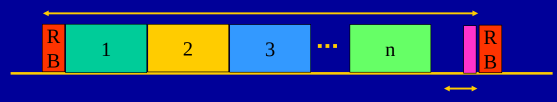
frame duration



ACQUISITION OF SYNCHRONISATION

- late

frame duration



EFFICIENCY

- Single-carrier operation:
  - transfer capacity r = BΓ
  - spectral efficiency of modulation scheme Γ (bits/s Hz)
  - channel bandwidth: B
  - t_i time devoted to non-traffic bits (guard time, preamble)

$$\eta = 1 - \sum \frac{t_i}{T_F}$$

THROUGHPUT

- Increases, when
  - T_F is high
  - t_i is low
- high T_F: high latency, undesirable .g. for voice
- dependent on number of active stations (traffic bursts)

THROUGHPUT

- P number of traffic bursts in frame
- p bits in preambel
- g equivalent bits of guard time

$$\eta = 1 - (P+1)(p+g)/rT_F$$

reference burst

TRAFFIC ROUTING TECHNIQUE

- one carrier per link: P = N(N-1)
- one carrier per transmitting station
  P = N
- one carrier per transmitting station advantageous, less carriers, higher efficiency

FRAME DURATION CONSIDERATIONS

- Interface-to-interface delivery delay: round-trip propagation time + T_F
- CCITT Recommendation G 114: delay between telephone subscribers must not exceed 400 ms

FRAME DURATION CONSIDERATIONS

- max. roundtrip: 278 ms
- allowing 50 ms in terrestrial tails

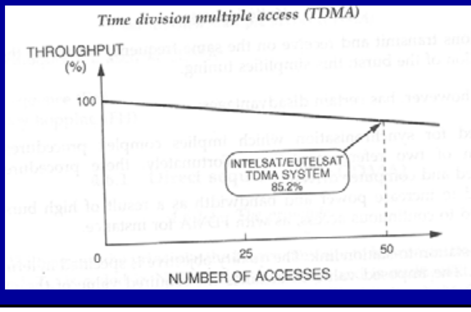
$$T_F \leq (400 - 278 - 50) = 72ms$$

- in practice: 0.75…50 ms

GUARD TIME AND PREAMBLE

- reduction of guard time by precise synchronization
  - closed loop preferable
- reduction of preambles:
  - advanced demodulator design

EXAMPLE: EFFICIENCY OF INTELSAT/UTELSAT TDMA SYSTEMS



CONCLUSION

- single carrier at any given time
- no intermodulation
- no (or limited) need to control power of stations
- better power efficiency
- high throughput, even for large number of accesses

CONCLUSION (2)

- all stations are on same frequency
  - simplified tuning
  - however, burst-to-burst variation should be < +/- 1.5 kHz
- need for synchronization (complexity)
- increase power and bandwidth as result of high burst bit rate

DISADVANTAGE

- Station equipment must be able to utilize whole carrier
- Network bandwidth limited
- Number of accesses limited