TDMA

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

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

- One station acts as the synchronizing master
- Transmits at regular intervals a reference burst
- Reference burst used to synchronize all stations
- Frame structure

SYNCHRONIZATION

FRAME STRUCTURE

- 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

SYNC. PREAMBLE

UNIQUE WORD

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

CORRELATOR

- N-stage shift register
- Data
- Majority decision
- Detect
DETECTION THRESHOLD

- Allowable errors in UW:
  - \( D = N - m = 0, 1, 2, 3, \ldots \)
  - 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

PERFORMANCE OF DETECTOR

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

UNIQUE WORD

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

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

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

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: \( \frac{1}{2.10^{-6}} \cdot \frac{20}{10^{-9}} = 25 \) s before corrective measure needs to be taken

**Burst Format**

- Preamble
- Guard Time
- TDMA Burst
- Burst Payload
- TDMA Burst

**Round-trip time variation of a geostationary satellite**

- Graph showing variation in round-trip time from 9:00:00 to 15:00:00 and 21:00:00 to 3:00:00, with peak at 12:00:00.
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 SOTF\( n \) + 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 \( m = 14 \), \( T_f = 20 \text{ ms} \), 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
- \( d_{n(i)} \) value observed on reception of frame for which \( D_{n(i)} \) was determined

BURST POSITION ERROR
- \( e_n(i) = d_{n(i)} - d_n \)
- station changes \( D_n \):
  \( D_n(i+1) = D_n(i) - e_n(i) \)

  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

![Diagram of early frame duration](image1)

- late

![Diagram of late frame duration](image2)
EFFICIENCY
- Single-carrier operation:
  - transfer capacity \( r = B \Gamma \)
  - spectral efficiency of modulation scheme \( \Gamma \) (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. e.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

\[
\eta = 1 - \frac{(P + 1)(p + g)}{r T_F}
\]

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

\[
T_F \leq (400 - 278 - 50) = 72 \text{ms}
\]

- 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