UNIT-V : Multiple Access (1)

- The ability of the satellite to carry many signals at the same time is known as **multiple access**.

Multiple ~~att~~ access allows the communication capacity of the satellite to be shared among a large number of earth stations, and to accomodate the different mixes of communication traffic that are transmitted by the earth stations.

A large GEO satellite may have comm. BW > 200MHz within an allocated spectrum of 500MHz.

The spectrum can be reused several times over – as many as 7 times (in case of INTELSAT IX satellites) by the frequency ~~frequency~~ reuse with
1. Multiple antenna beams and
2. Orthogonal polarization.

The signals that earth stations transmit to a satellite may differ widely in their character – 1. voice
2. video
3. data
4. fascimile (FAX)

- These signals can be sent through the same satellite using multiple access and multiplexing techniques.

Multiplexing: is the process of combining a number of signals into a single composite signal, so that it can be processed by a single amplifier or transmitted over a single radio channel.

Multiplexing can be done at baseband or radio frequency.

- Multiplexing is a key feature of all commercial long distance communication systems, and is a part of the multiple access capability of all satellite communication systems.
- The multiple access technique will influence: (1) The capacity,
(2) The flexibility
(3) Cost
(4) Revenue of satellite comm. sys.
- The basic problem in any multiple access system is:
(1) how to permit a changing group of earth stations to share a satellite in such a way that satellite comm. capacity is maximized,
(2) BW is used efficiently,
(3) flexibility is maintained, and
(4) Cost to the user is minimized while revenue to operator is maximized.
(5) also allow for changing patterns of traffic over 10 or 15 years of the expected life time of the satellite.

NOTE: Usually all of these requirements cannot be satisfied at the same time and some may have to be traded off against others.

- There are 3 basic multiple access techniques
1. FDMA (Frequency Division Multiple Access)
2. TDMA (Time Division Multiple Access)
3. CDMA (Code " " ")
- In FDMA, all users share the satellite at the same time, but each user transmits at a unique allocated frequency.

Ex: Radio broadcasting (Each radio station is allocated ~~of~~ a frequency and BW).

- FDMA can be used with analog ...

In TDMA, each user is allocated a unique time slot at the satellite so that signals pass through the transponder sequentially.

TDMA is used only with digital signals, ~~It causes~~ TDMA causes delays in txn.

In CDMA, all users transmit to the satellite on the same frequency and at the same time.

The earth stations transmit orthogonally coded spread spectrum signals that can be seperated at the receiving earth station by correlation with the transmitted code.

CDMA is inherently a digital technique.

NOTE: In each of the multiple access techniques, some unique property of the signal (frequency, time, or code) is used to label the transmission that the wanted signal can be recovered at the receiving terminal in the presence of all other signals.

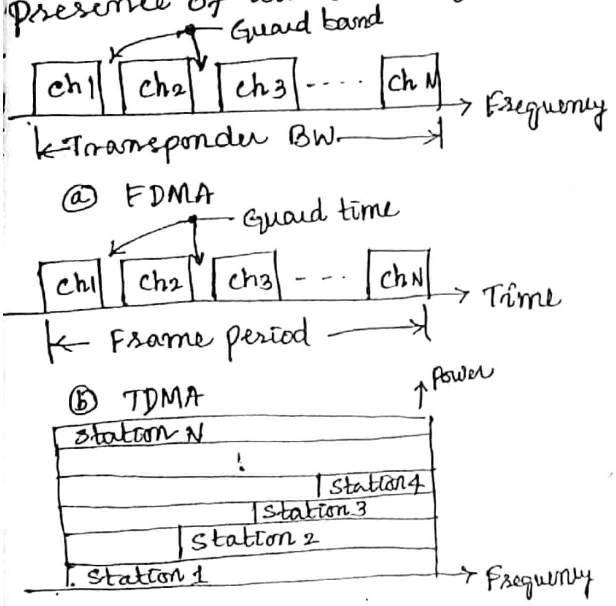


Fig. Multiple access techniques

(2) Difference between Multiplexing and Multiple Access

- Multiplexing applies to signals the generated at one location, whereas multiple access refers to signals from a no. of different geographical location.

Ex: TDM → High speed data stream for many digital speech channels delivered to that earth station → RF carrier modulation.

- The RF carrier can share a transponder using TDMA / FDMA with other carriers from earth stations anywhere within the satellite's coverage zone.
- The resulting signal is called TDM-TDMA or TDM – FDMA.

NOTE: The distinction between TDM and TDMA signals at one earth station are combined by multiplexing, and then share a satellite transponder with signals from other earth stations by multiple access.

Access Schemes (types)

(1) Fixed access (FA) or preassigned access (PA)

- If the proportion (time, frequency/code) allocated to earth station is fixed in advance, the system is called FA & PA.

(2) Demand Access (DA)

- If the resource is allocated as needed depending on changing traffic conditions the multiple access technique is called DA.

Ex: FDMA-DA system transmit only when they have traffic – Used in VSAT Systems

- TDMA-DA system used in VSATs and Mobile Satellite Systems.
- CDMA-DA: used in Globstar LEO mobile satellite system.

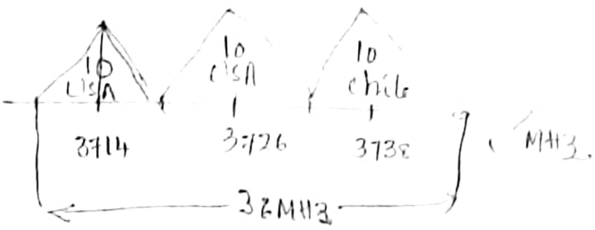
F-DMA

1960's — Satellites carry telephony
l signals were analog, and analog
ultipling was used at earth stations
mbine large numbers of telephone
nnels into a ~~big~~ single baseband
nal that could be modulated onto
ingle RF carrier.
ividual telephone channels can be
ifted in frequency from baseband to
igher frequency, so that they can be
ced into a group of channels using
).

Process begins by limiting telephone
annels to frequency range 300-3400 Hz
d then frequency shifting 12 channels
frequency range 60–108 kHz with
kHz spacing between channels by
nerating SSB-SC with 12 carrier frequencies
aced 4 kHz apart.
ne 12 channels occupying 60-108 kHz
e known as Basic group [Fig. B.3, pp: 494].
ive basic groups can be frequency shifted
the range 60-300 kHz to make a 60
)-channel supergroup occupying a
seband BW of 240 kHz (Fig. B.4, pp: 495).
uper groups can be stacked in the
aseband to make up single signals
at consists of 300, 600, 900 or 1800
ultiplexed telephone channels.

E: The analog FDM is obsolete now.
d satellites uses FDM–FM–FDMA system.
FDMA advantage: filters can be used
to separate signals.

(3) Transponder 1



Transponder 2

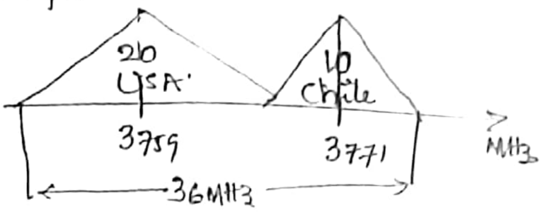


Fig. Frequency plan for 2 C-band transponders using FDMA.

- Typical Intelsat FDM carrier with a BW of 10 MHz carried 132 or 252 telephone channels.
- With fixed assignment, the frequencies and satellite capacity can not be reallocated between routes, so much of satellite capacity remains idle.
- Estimates of average loading of Intelsat satellites using fixed assignm are typically 15%.
- Demand assignment and single channel per carrier (SCPC) allows higher loadings and give satellite operators increased revenue.
- SCPC system can have a large no. of carriers in one transponder.
- Typical guard bands of 10 to 25% of the channel BW are needed to minimize adjacent channel interference.

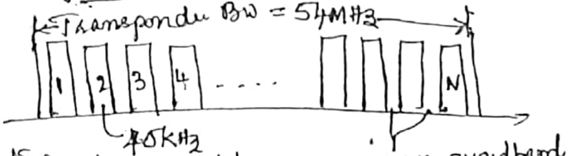


Fig. Ku-band transponder
Digital

FDM-FM-FDMA was a telephone transmission technique well suited to analog telephone signals.

Telephony has become digital and FDM replaced by TDM.

The T1 (64kbps) or DS-1 Carriers are examples of lower speed digital multiplexed carriers.

Optical networks carry OC-48 at rate of 2.5Gbps (high speed digital signal).

Allocating a wideband transponder to a single narrow bandwidth signal is clearly wasteful, so FDMA is a widely used technique.

When an earth station sends one signal on a carrier, the FDMA access technique is called single channel per carrier (SCPC).

Thus, a system in which a large no. of small earth stations, such as mobile phones, access single transponder using FDMA is called SCPC-FDMA.

Hybrid multiple access schemes can use TDM of baseband channels which are then modulated onto a single carrier.

A no. of earth stations can share a transponder using FDMA, giving a system known as TDM-SCPC-FDMA.

TDM-SCPC-FDMA is used by VSAT networks in which the earth stations carry more than one baseband signal.

Disadvantage of FDMA: When transponder has a non linear characteristics.

Most satellite transponders use HPA using TWTA is more prone to nonlinearity than [illegible] solid state HPA (SSHPA).

- Equalization at the transmitting station, in the form of predistortion of the transmitted signal, can be employed to linearize the transponder when fixed assignment is used.
- Linearization of solid state and TWT HPAs on the satellite is also possible.
- Non linearity of the transponder HPA causes a reduction in the overall (C/N₀) ratio at the receiving earth station, when FDMA is used because intermodulation products (IM) are generated in the transponder.
- Some of the IM products will be within the transponder bandwidth and will cause interference.

- The IM products are treated as though they were thermal noise, adding to the total noise in the receiver of the receiving earth station.
- IM power increases as the cube of the signal power in dB units, every 10dB increase in signal power causes a 30dB increase in IM-product power.
- Consequently, the easiest way to reduce IM problems is to reduce the level of the signals in the HPA.

HW: Prove that IM products increase in proportion to the cubes of the signal powers in a satellite transponder when FDMA is used.

Intermodulation

- IM products are generated whenever more than one signal is carried by a non-linear device.
- Sometimes filtering can be used to remove the IM products, but if they are within the BW of the transponder they can not be filtered out.
- The saturation characteristic of a transponder can be modelled by cubic curve to illustrate the 3rd order intermodulation.
- 3rd order IM products often have frequencies close to the signals that generate the intermodulation, and are therefore likely to be within the transponder BW.
- Consider a HPA with cubic voltage relationship and apply two unmodulated carrier frequencies f_1 and f_2 at the i/p of the amplifier.

$$V_{out} = A V_{in} + b (V_{in})^3 \rightarrow ①$$

where $A \gg b$.

The amplifier i/p signal is

$$V_{in} = V_1 \cos \omega_1 t + V_2 \cos \omega_2 t \rightarrow ②$$

The amplifier o/p signal is

$$V_{out} = A V_{in} + b \underbrace{(V_{in})^3}_{\text{linear term}}$$

$$= \overbrace{A V_1 \cos \omega_1 t + A V_2 \cos \omega_2 t}^{\text{linear term}} \quad (f_1, f_2)$$

$$+ \underbrace{b (V_1 \cos \omega_1 t + V_2 \cos \omega_2 t)^3}_{\text{cubic term}} \rightarrow ③$$

The linear term simply amplifies the input signal by a voltage gain A.

The cubic term denoted as V_{3out} can be expanded as

$$V_{3out} = b (V_1 \cos \omega_1 t + V_2 \cos \omega_2 t)^3$$

$$= b [\underset{①}{V_1^3 \cos^3 \omega_1 t} + \underset{②}{V_2^3 \cos^3 \omega_2 t} \rightarrow (3f_1, 3f_2)$$

$$+ 3 V_1^2 \cos^2 \omega_1 t \cdot V_2 \cos \omega_2 t$$

$$+ 3 V_2^2 \cos^2 \omega_2 t \cdot V_1 \cos \omega_1 t)] \rightarrow ④$$

(5) • The first two terms contain frequencies f_1, f_2, $3f_1$ and $3f_2$.

- The triple frequency components $3f_1$, $3f_2$ can be removed from the amplifier output by using a BPF.

- The second two terms generate the 3rd order IM frequency components.
- We know that $\cos^2 x = \frac{1}{2} [\cos 2x + 1]$

$$\therefore V_{IM} = 3 b V_1^2 \times V_2 [\cos \omega_2 t \times (\cos 2\omega_1 t + 1)]$$

$$+ 3 b V_2^2 \times V_1 [\cos \omega_1 t \times (\cos 2\omega_2 t + 1)]$$

$$= \frac{3}{2} b V_1^2 \times V_2 [\cos \omega_2 t \cdot \cos 2\omega_1 t + \cos \omega_2 t]$$

$$+ \frac{3}{2} b V_2^2 \times V_1 [\cos \omega_1 t \cdot \cos 2\omega_2 t + \cos \omega_1 t] \rightarrow ⑤$$

- The terms at frequencies f_1 and f_2 add to the wanted output of the amplifier.
- So the 3rd IM products are generated by the $f_1 \times 2f_2$ and $f_2 \times 2f_1$ terms.
- We know that $2 \cos x \cdot \cos y = \cos(x+y) + \cos(x-y)$
- The o/p of the amplifier contains IM frequency components given by

$$V_{IM}' = \frac{3}{4} b V_1^2 \times V_2 [\cos (2\omega_1 t + \omega_2 t) + \cos (2\omega_1 t - \omega_2 t)]$$

$$+ \frac{3}{4} b V_2^2 \times V_1 [\cos (2\omega_2 t + \omega_1 t) + \cos (2\omega_2 t - \omega_1 t)] \rightarrow ⑥$$

- We can filter out the sum terms in eq ⑥ but the difference terms with frequencies $(2f_1 - f_2)$ and $(2f_2 - f_1)$ may fall within the transponder BW.
- These two terms are known as 3rd IM products of HPA.
- Thus, the 3rd order IM products that are concern are given by V_{3IM} where

$$V_{3IM} = b \cdot V_1^2 V_2 \cos (2\omega_1 t - \omega_2 t)$$

$$+ b V_2^2 \cdot V_1 \cos (2\omega_2 t - \omega_1 t) \rightarrow ⑦$$

- The magnitudes of IM products depends on the parameter 'b', which describes the non linearity of the transponder, and the magnitude of the signals.
- The wanted signals at the transponder o/p at frequencies f_1 and f_2, have magnitude

(6)

Then the wanted output from the amplifier is:

$$V_{out} = AV_1 \cos\omega_1 t + AV_2 \cos\omega_2 t.$$

The total power of the wanted o/p from a HPA, referenced to a 1 Ω load, is therefore

$$\boxed{P_{out} = \tfrac{1}{2}A^2V_1^2 + \tfrac{1}{2}A^2V_2^2 = A^2(P_1+P_2)}\ W \rightarrow (8)$$

where P_1 and P_2 are the power levels of the wanted signals.

The power of the IM products at the o/p the HPA is

$$P_{IM} = 2 \times \left(\tfrac{1}{2}b^2V_1^6 + \tfrac{1}{2}b^2V_2^6\right)$$

$$\boxed{P_{IM} = b^2(P_1^3 + P_2^3)\ W} \longrightarrow (9)$$

It can be seen that IM products increase in proportion to the cubes of the signal powers, with power levels that depend on the ratio $(b/A)^2$.

If the nonlinearity of the HPA is greater (larger b/A ratio) then the IM products are larger.

Ex:. Consider 36-MHz BW transponder

Down link: 3705 - 3741 MHz

Transponder carries two unmodulated carriers at 3718 (f_1) and 3728 (f_2) MHz with equal magnitudes at the i/p of HPA.

- The o/p HPA contain additional frequency components at frequencies

$$f_{31} = (2 \times 3718 - 3728) = 3708 \quad (\because 2f_1 - f_2)$$

$$f_{32} = (2 \times 3728 - 3718) = 3738\,MHz \quad (2f_2 - f_1)$$

Both IM freq. are within the transponder BW and therefore be present in an earth station Rx that is set to the frequency of this transponder.

Consider two signals carry modulation which spreads the signal energy into a BW of 8 MHz.

- Carrier 1 has frequencies 3714 to 3722 MHz (f_{1lo} to f_{1hi}) → BW = B_1 = 8 MHz
- Carrier 2 has frequencies 3726 to 3734 MHz (f_{2lo} to f_{2hi}) → BW = B_2 = 8 MHz
- Then the intermodulation products cover $(2f_{1lo} - f_{2hi})$ to $(2f_{1hi} - f_{2lo})$ and $(2f_{2lo} - f_{1hi})$ to $(2f_{2hi} - f_{1lo})$.

Hence the 3rd order IM products covers

$$\underbrace{3694 \text{ to } 3718}_{BW = 2B_1 + B_2 = 24\,MHz} \text{ and } \underbrace{3730 \text{ to } 3754}_{2B_2 + B_1 = 24\,MHz}$$

Fig. 6.4 Frequency values are wrong Pp. 228

Calculation of C/N with intermodulation

$$\left(\frac{C}{N}\right)_0 = \frac{1}{\left[\frac{1}{(C/N)_{up}} + \frac{1}{(C/N)_{dn}} + \frac{1}{(C/N)_{IM}}\right]}$$

Power ratios

$(C/N)_0$: overall C/N ratio at earth station Rx

$(C/N)_{up}$: ~~IM noise~~ in the transponder in up link HPA

$(C/N)_{dn}$: Down link HPA

$(C/N)_{IM}$: IM noise in transponder

TDMA:

- In TDMA, a number of earth stations take turns transmitting bursts of RF signals through a transponder.

Advantages of TDMA

1. In TDMA systems, because the signals are digital and can be divided in time
   - are easily reconfigured for changing traffic demands,
   - are resistant to noise and interference
   - and can readily handle mixed voice video and data traffic.
2. In TDMA, entire BW of a transponder is used by an earth station during slot assi
   - only one signal is present in the transponder at any time, hence no problem with non linear ...

Disadvantages of TDMA

1. Every earth station is to transmit data at a high bit rate since the earth station can use the entire BW of the transponder during the time slot assigned.
2. High data rate transmission requires high transmitter power.
3. TDMA is not well suited to narrow band signals from small earth stations.

- Non linearity in the transponder can cause an increase in ISI with digital carriers
  - Equalizers can be used at the receiving earth stations to mitigate the effect of ISI.

Difference between TDM and TDMA

- TDM is a baseband technique used at one location (ex. txing earth station) to multiplex several digital bit streams into a single higher speed digital signal.
- Groups of bits are taken from each baseband packet or signal and formed into frames, that can also contain synchronization and identification bits.
- The clock frequency for the bit stream is fixed and frame length is usually constant.

NOTE: However, packet lengths can vary

- The entire process requires considerable storage of bits, so that the original signals can be rebuilt, leading to delays in transmission.

In GEO satellite system, the largest delay is always the transmission time to the satellite and back to earth is

(7) The transmission delay [illegible] but any additional delays should be minimized.

TDMA: is an RF multiple [illegible] that allows a single transponder to be shared in time between RF carriers from different earth stations

- The RF carrier from each earth station sharing a transponder is sent as a burst at a specific time
- At the satellite, bursts from different earth stations arrive sequentially, so that transponder carries a near continuous signal made up of a sequence of short bursts coming from different earth stations.
- The burst transmission is assembled at the txing earth station, so that it will correctly fit into the TDMA frame at the satellite.
- The frame has a length from 125 μs to many ms, and the burst from the earth station must be transmitted at the correct time to arrive at the satellite in the correct position within the TDMA frame.
- This requires synchronization of all earth stations in a TDMA n/w.
- Each station must know exactly when to transmit (within a μs), so that RF bursts arriving at the satellite from different earth stations do not overlap.

NOTE: A time overlap of two RF signals is called a collision and results in data in both signals being lost.

- Collisions must not be allowed to occur in a TDMA system
- A receiving earth station must synchronize its receiver to each of the [illegible]

d recover the transmission from
ch uplink earth station.

hen the uplink transmissions are broken down to extract the data bits, which are stored and reassembled into their original bit streams.

he uplink earth stations are usually sent using BPSK or QPSK, and will inevitably have small differences in carrier, ~~and~~ clock frequencies and different carrier phases.

The Rxing earth stations must synchronize its PSK demodulator to each burst of signal within few μs.

In high-speed TDMA systems, operating at 120 Mbps are required in TDMA systems.

3its, symbols and channels

Generally QPSK/QAM modulation is used by transmitting earth stations.

En QPSK, two bits at a time are converted into one of four phase states of the RF carrier.

The state of RF carrier is called a symbol.

The symbol rate in in units of bauds or symbols per second.

For BPSK → Bit rate = Baud rate

- For QPSK ⇒ Baud rate (symbol rate) $= \frac{1}{2} \cdot$ Bit rate

MA Frame structure

A TDMA frame contains the signals transmitted by all of the earth stations in a TDMA network.

It has a fixed length and is built up from the burst transmission of each earth station, with guard times between each burst.

The frame exists in the satellite transponder ... from the satellite

(8) • Figure below shows a TDMA frame for 4 txing earth stations.

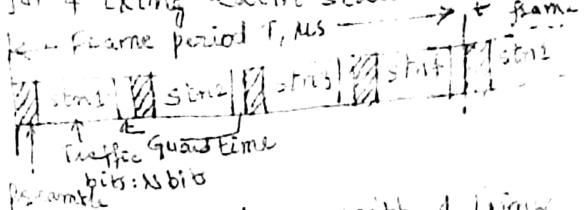


Fig. TDMA frame with 4 txing earth stations.

• Each station transmits a preamble that contains synchronization and other data essential to the operation of the n/w before sending data.

• The earth station's transmission is followed by a guard time to avoid possible overlap of the following transmissions.

• In GEO satellite systems, frame length of 125 μs up to 20 ms have been use — 2 ms has been widely used in Intelsat.

• The time t_d, available in each station burst for transmission of data bits is

$$\boxed{T_d = [T_{frame} - N(t_g + t_{pre})]/N \text{ seconds}} \quad \to (1)$$

where T_{frame} = duration of frame (seconds)

t_g = guard time (s)

t_{pre} = preamble length (s)

N = No. of earth stations

• In 1 second, the total no. of bits, C_b, transmitted by each earth station is:

$$\boxed{C_b = [T_{frame} - N(t_g + t_{pre})] \times \frac{R_b}{N \times T_{frame}}} \quad \to (2)$$

$$\boxed{C_b = t_d \cdot \frac{R_b}{T_{frame}}}$$

where R_b = Txed bit rate of the TDMA system

• Since, each digital speech channel requires a continuous bit rate of r_{sp} bps, the no. of speech channel that can be carried by each earth station is given by 'n' where

$$\boxed{n = [T_{frame} - N(t_g + t_{pre})] \times \frac{R_b}{\dots}} \quad \to (\dots$$

each stations must be able to (1) join the network, add their bursts to the TDMA frame in the correct time sequence, and leave the N/W without disrupting its operation.

- They must also be able to track changes in the timing of the frame caused by motion of the satellite toward or away from the earth station.

Each earth station must also be able to extract the data bits and other information from burst transmissions of other earth stations in the TDMA N/W.

- The transmitted burst must contain synchronization and identification information that help receiving earth stations to extract the required information without error.

TDMA transmissions are divided into two parts: ① a preamble containing all the synchronization and identification data, ② a group of traffic bits

- synchronization of TDMA N/W is achieved with the operation portion of the preamble transmitted by each earth station that contains carrier and bit clock synchronization waveforms.

In some systems, a seperate reference burst may be transmitted by one of the stations, designated as the master station.

- A reference burst is a preamble followed by no traffic bits.

- The traffic bits are the revenue producing portion of each frame,
- The preamble and reference burst are overhead.

NOTE: The smaller the overhead, the more efficient the TDMA system [illegible]

[illegible]

transmission [illegible]

- A longer frame contains proportionally less preamble time than a short frame so more revenue producing data bits can be carried in a long frame.

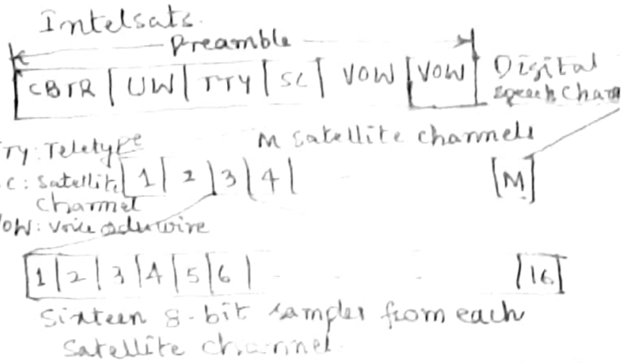
- Early TDMA systems were designed around 125 μs frames, to match the sample rate of digital speech in telep
- However, it is more efficient to length the frame to 2ms or longer, so that the portion of overhead to message transmission time is reduced.

Ex: 4KHz → 8000 samples/sec → $T = \frac{1}{8000} = 125\,\mu s$

$\frac{2\,ms}{125\,\mu s}$ = 16 Digital Speeches
16 Eight bit words

- So, a 2 ms TDMA frame requires 16 eight-bit words from each terrestrial channel in each Tx burst.

- Fig. below shows a typical TDMA frame with 2.0ms duration used Intelsats.



TTY: Teletype
SC: satellite channel
VOW: voice orderwire

Fig. structure of an Intelsat traffic data burst.

CBTR: Carrier and bit timing recovery

- carrier recovery is required at the Rx of any radio link in which coherent PSK/QPSK is the modulation technique.
- Once the carrier phase lock is achieved the demodulator [illegible]

The CBTR contains a sequence of predetermined signals that ensure rapid lock to the carrier and fast synchronization of the bit clock.

The carrier recovery portion of the CBTR sequence may consists of unmodulated carrier followed by a number of symbols that follow specific pattern, or the entire CBTR burst may be modulated.

The first part of CBTR burst is used to obtain lockup of the PLL, and the remaining portion is used for bit clock synchronization.

CBTR burst has a duration of 176 symbols, with tx rate of 30Msps, giving a burst duration of 5.86 μs.

Within this very short period, the carrier recovery ckt must achieve precise lock on the received signal and the bit clock must be brought into synchronization.

Typical TDMA systems using QPSK send the first 48 or 50 symbols of the CBTR burst as all ones or all zeros on both the I and Q phases of the carrier, which corrospond to sending an unmodulated carrier, followed by a sequence of ones and zeros in both channels.

UW: Unique word of typically 20 to 48 bits.

- It acts as a transmit station identifier, a start of frame (SOF) or burst marker and as carrier phase ambiguity detector.

The received bit sequence at the demodulator output is continuously run through a correlator which looks for the appearance of the unique word in the bit stream.

Fig. below shows the unique word correlator.

The correlator is looking for a match between the incoming bit pattern and [illegible] ... [illegible]

(10) [illegible] bits of the sequence are inverted [illegible] phase ambiguity in the carrier recovery ckt.

- A [illegible] received [illegible] for ambiguity resolu[tion]

- The pattern of [illegible] and zeros in the CB[TR] sequence and the unique word allow the receiver to check for phase ambiguity and to invert the appropriate bit stream (I, Q or both) if ambiguity is found.

- In fig. below, when the correct UW sequence is present in the correlator in the correct position (i.e at the correct time within the incoming signal burst) the correlator output will maximize and trigger the detector.

Fig. Unique word correlator

- When a new RF burst is received the carrier recovery circuit locks the local carrier PLLs and bit clock then synchronizes to the bit rate of the received signal.

- There must be as many UW correlators as there are TDMA uplink stations in the N/W when the UW is also used as a station identifier.

- If there is a large number of stations it is simpler to use a single UW and seperate station identifier word.

... stream for each received burst is tagged with a station identifier so that the demultiplexer in the earth station can route the data accordingly.

TTY: 16 bits (8QPSK symbols) in each burst are allocated to a teletype link between the earth stations, and a further 16 bits

SC: Another 16 bits to a service channel.

VOW: there are 64 bit voice order wire that is used in digital voice links between earth stations.

The TTY and VOW channels provide a closed communication N/w between the control stations that is used to manage the TDMA system.

Traffic data:

- It uses 2ms frame
- Speech data could be carried in satellite channels as sixteen 8-bit words from each terrestrial channel, giving a satellite channel 128 bits in each burst.

The bits associated with each satellite channel are demultiplexed by counting the 128 bits of each satellite channel, beginning at end of the preamble.

Guard times

must be provided between bursts from each earth station so that collisions are avoided.

Earth stations must transmit their bursts at precisely the correct instant so that the burst arrives at the satellite in the correct position within the TDMA frame.

This requires burst transmission timing to μs accuracy and tracking of the ... burst within the TDMA frame

- Long guard times make it easier for the earth station to avoid collision but waste time that could be used to send revenue-earning traffic.
- Typical guard times in high-speed satellite networks appear to be in the range 1 to 5 μs.
- The t_x time between an earth station and a GEO satellite is about 120ms
- If a 2ms frame time is used, there are typically 60 bursts between the earth station and satellite at any time
- The bursts must arrive at the correct time to mesh between the burst between that arrive from other earth station
- If the satellite range from the earth station increases by 300m, due to eccentricity or inclination of a GEO satellite's orbit. Then the transmission delay increases by 1 μs.
- Thus earth stations must monitor the guard times before and after their burst to ensure that transmission timing is correct.
- In LEO satellite networks that use TDMA, the range to the satellite is changing continuously and much larger guard times are allowed.

Synchronization in TDMA N/Ws

- Earth stations operating ~~at~~ in a TDMA N/w must transmit their RF bursts at precisely controlled times such that burst from each of the earth stations arrive at the satellite in the correct sequence.

Problems: (1) How to start up a new earth station that is joining the TDMA N/w.

aintaining synchronization with
the TDMA frame is easier than initial
synchronization, when an earth station
joins a TDMA n/w.

One station is typically designated as
the master station, and may generate
a reference burst to mark the start
of the frame.

Each of the stations within the N/W
has a time slot within the frame, and must
maintain its transmissions within that
time slot.

There are guard times at each end of
each station's burst, which define the
accuracy that the burst timing must
achieve.

If the guard times are 2 μs, each earth
station in the N/W must keep its bursts
timed within 1 μs.

The start of the reference burst, or
the start of the master station's preamble,
marks the start of transmit frame (SOTF),
which is master timing mark for all
transmissions.

All earth stations in TDMA N/W synchronize
their clock timing with the SOTF
marker.

When an earth station monitors its
own transmissions to maintain the
correct burst timing, this is called
satellite loop-back synchronization.

The TDMA frame is established at the
satellite, so an earth station receiving
the frame must subtract the tx delay
from the satellite (120 ms) to the
earth station to obtain the SOTF timing
at the satellite.

...mit its bursts ahead
so that the bursts arrive at the
correct instant at the satellite.

Knowledge of the range of the satellite
from the earth station is crucial
in calculating delay times.

- The range can be calculated from
the orbital elements of the satellite
which can be determined by a control
station that repeatedly measures
range to the satellite.
- The availability of a global GPS time
standard with better than 1 μs
accuracy has made some of these
tasks easier.

Transmitter Power in TDMA N/W