

FRAME STRUCTURE & TIMING ADVANCE IN GSM

ECE 525E – WIRELESS & MOBILE COMMUNICATION

Friday, 10 February 2023

RECALL - NUMBER OF CHANNELS IN GSM

General

- **FDMA with Channel Freq:** 200 kHz
- **TDMA:** 8 time slots per frequency carrier

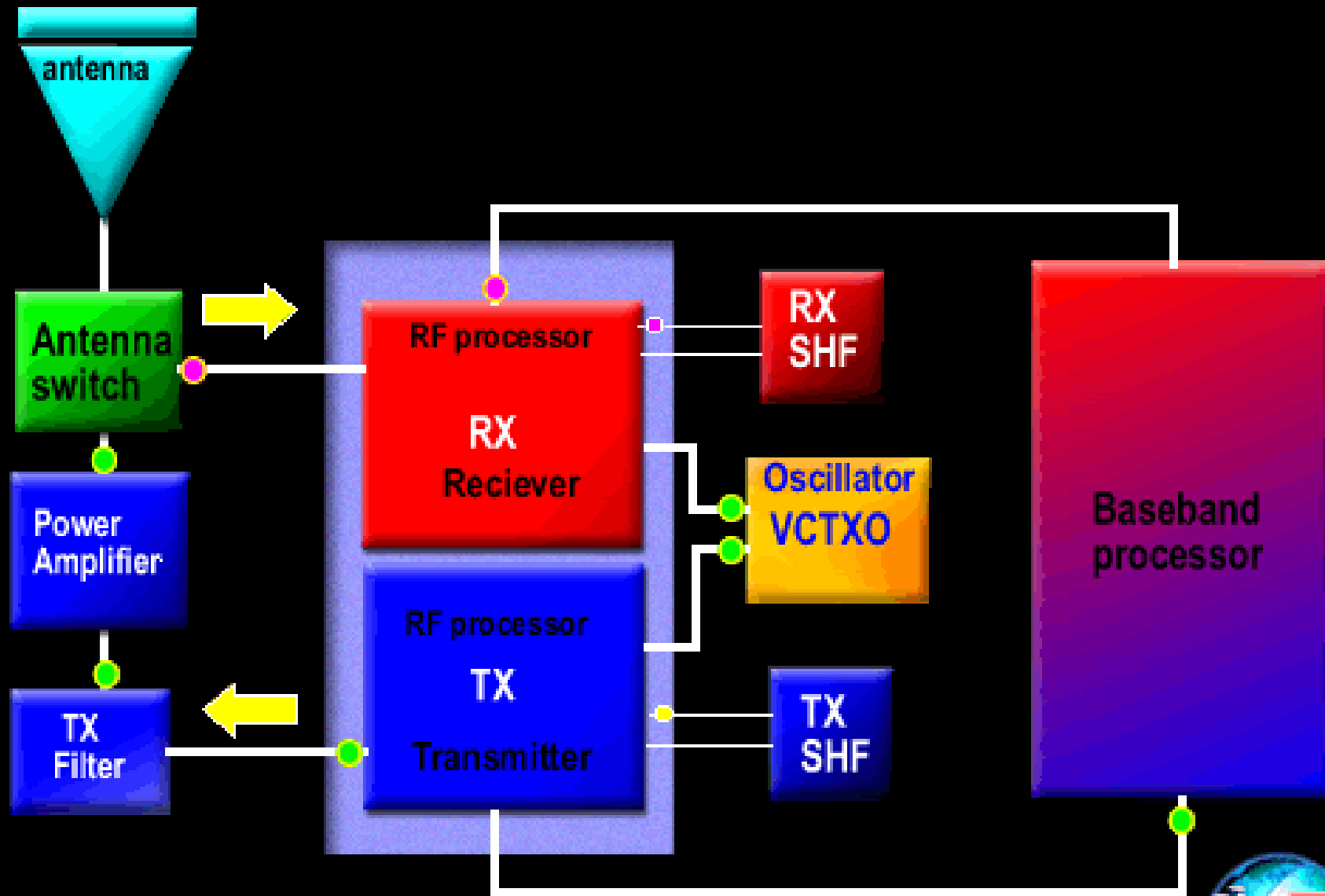
900 MHz Band

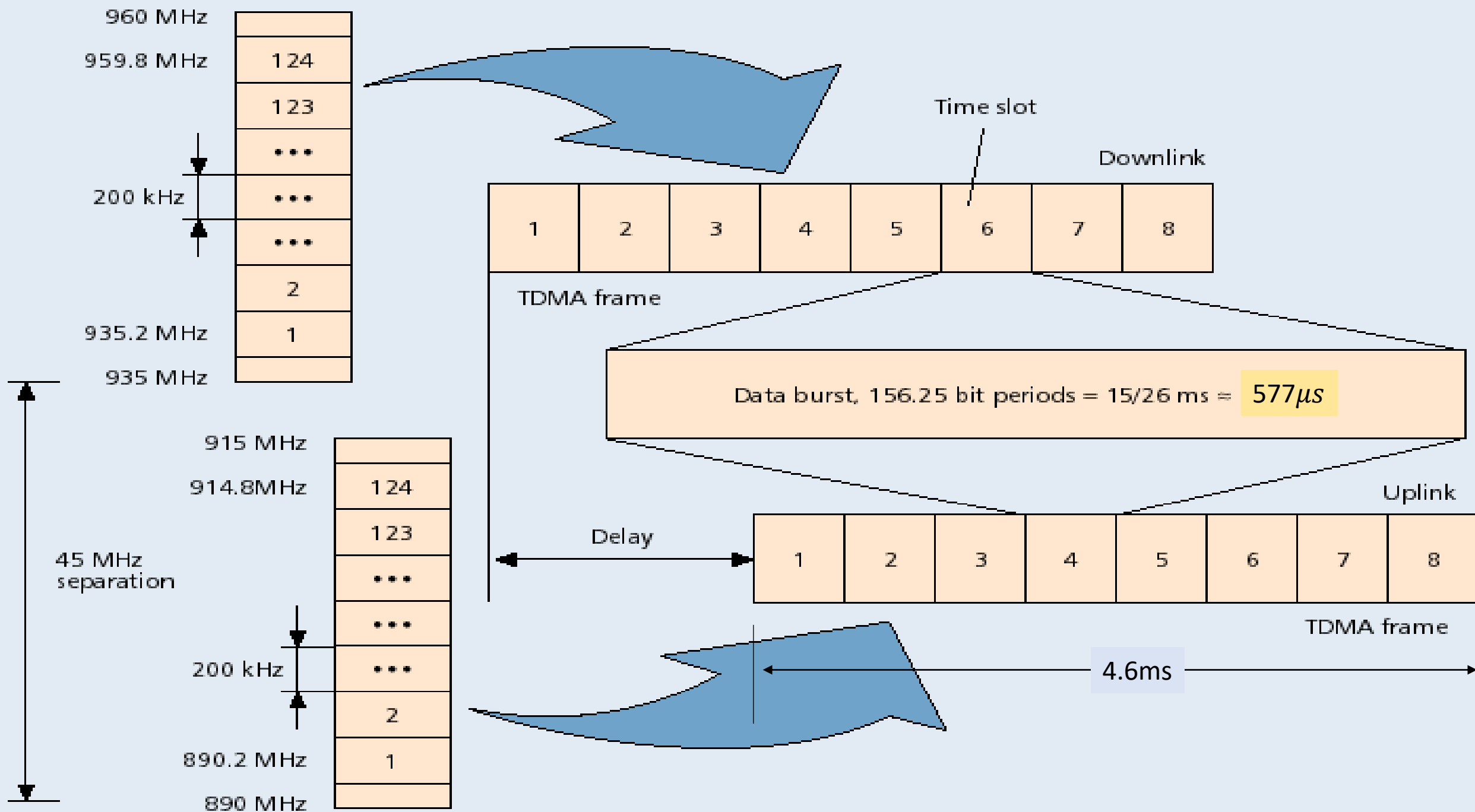
- **No. of carriers:** $25 \text{ MHz} / 200 \text{ kHz} = 25/0.2 = 125$
- **No. of user channels** = $125 * 8 = 1000$
- **Practical Considering guard bands** = $124 * 8 = 992$ channels

1800 MHz Band

- **No. of carriers:** $75 \text{ MHz} / 200 \text{ kHz} = 75/0.2 = 375$
- **No. of user channels** = $375 * 8 = 3000$
- **Practical Considering guard bands** = $374 * 8 = 2992$ channels

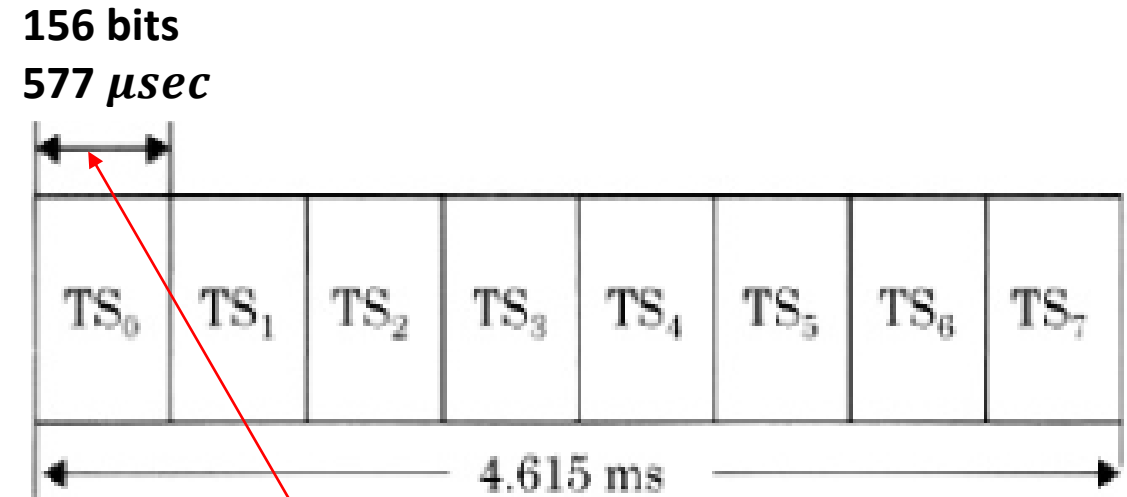
Typical Block Diagram of GSM Radio Frequency - RF Circuit





GSM FRAME STRUCTURE

1. GSM frame structure assumes that all Mobile stations are synchronized with the same clock.
2. In practice, the BTS transmits a sync signal in the SCH channel (logical) which is used by all MS in the cell for timing.
3. Everything will work very well if all MS were located at the same distance from the BTS.
4. In practice MS can be anywhere from a few meters to 35 Kms from a base station.
5. The GSM system, must therefore take into account the propagation delay.



$$\text{Bit Period} = 577/156 = 3.7 \mu s$$

DISTANCE	DELAY
1km	$= \frac{1 \times 10^3}{3 \times 10^8} = 3.3 \times 10^{-6}$
30km	$= \frac{30 \times 10^3}{3 \times 10^8} = 100 \times 10^{-6}$

LOGICAL CHANNELS

PCH

Paging Channel used by network to alert mobile for call from another calling mobile.

AGCH

Access Grant Channel carry information by which mobile will determine whether the access to the network has been granted

RACH

Random Access Channel is used by Mobile to access the GSM network during call set-up time

FACCH

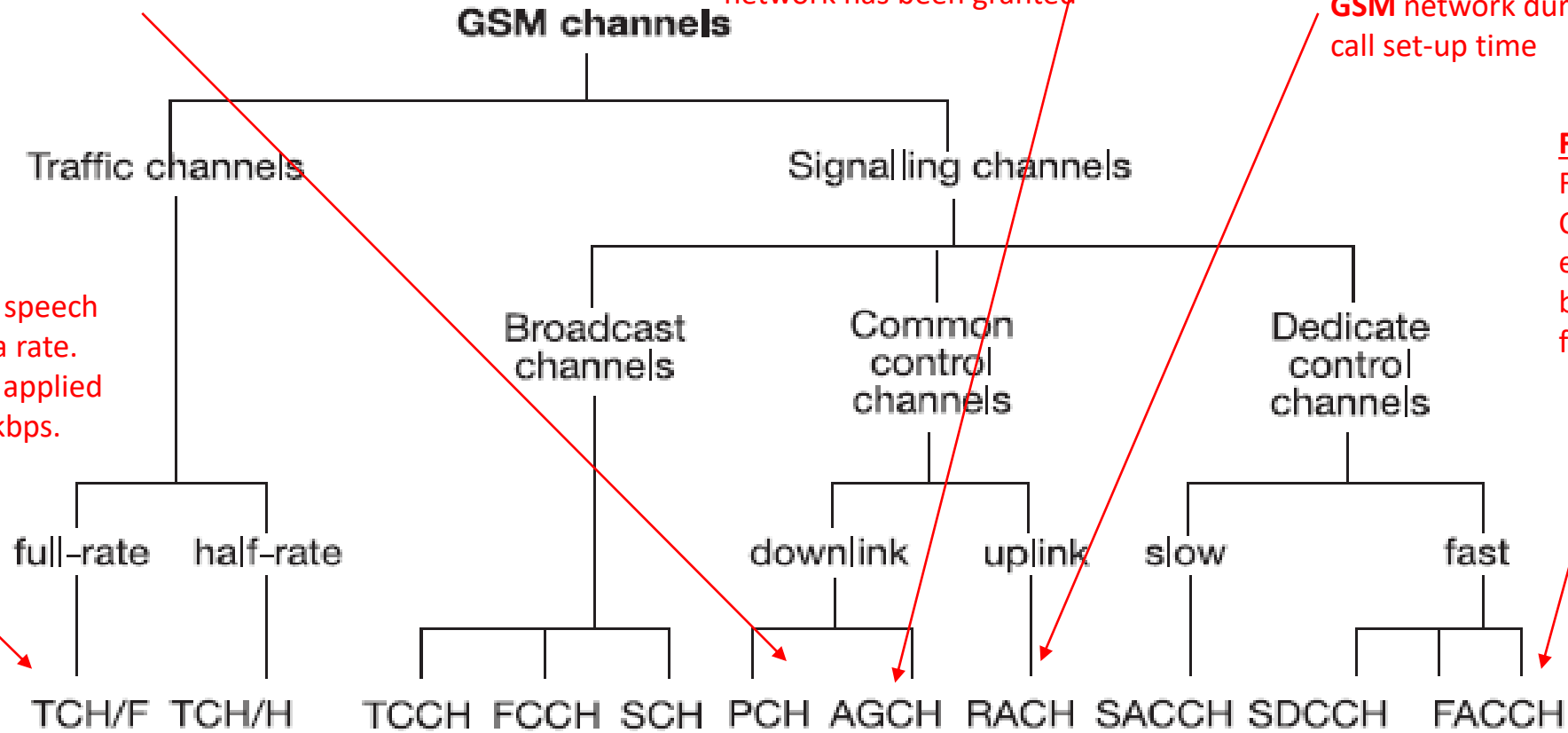
Fast Associated Control Channel is used to exchange information between MS and BTS faster than SACCH

TCH/FS

Traffic channel full rate speech digitized at 13kbps data rate. After channel coding is applied the rate becomes 22.8kbps.

TCH/H

Carries half rate speech. Two half rate TCH channels use one physical channel.

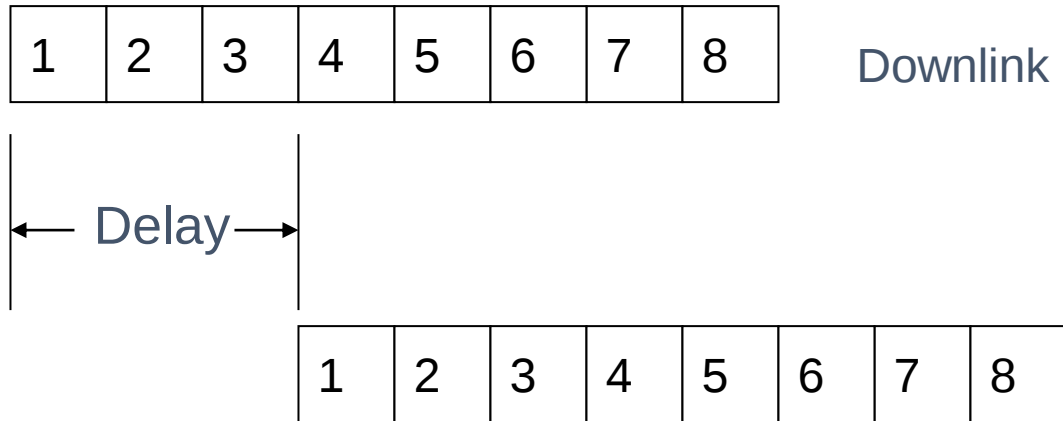


Note: These logical channels (type of burst) are then mapped onto Physical channels.

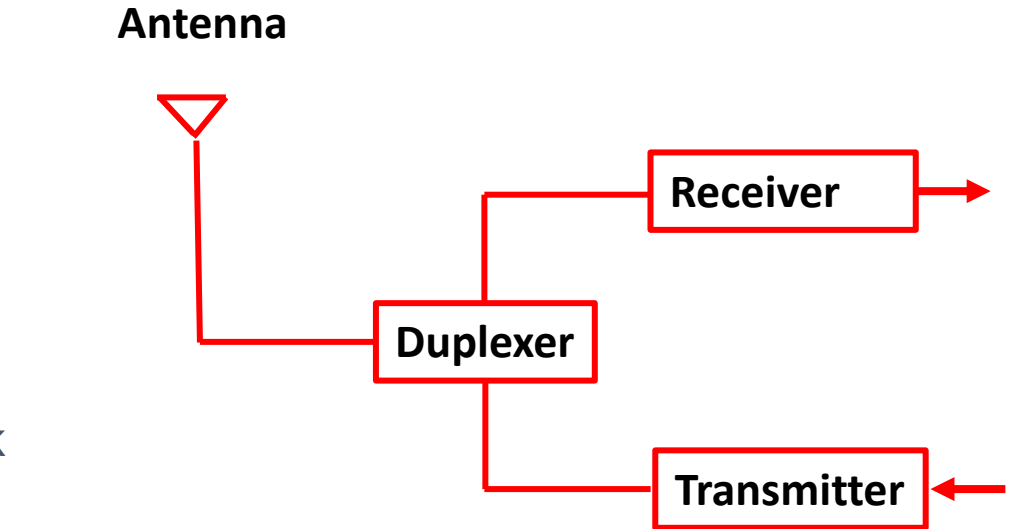
A GSM Physical channel comprises a particular timeslot on a given freq. Channel.

TRANSCIVER HARDWARE TIMING

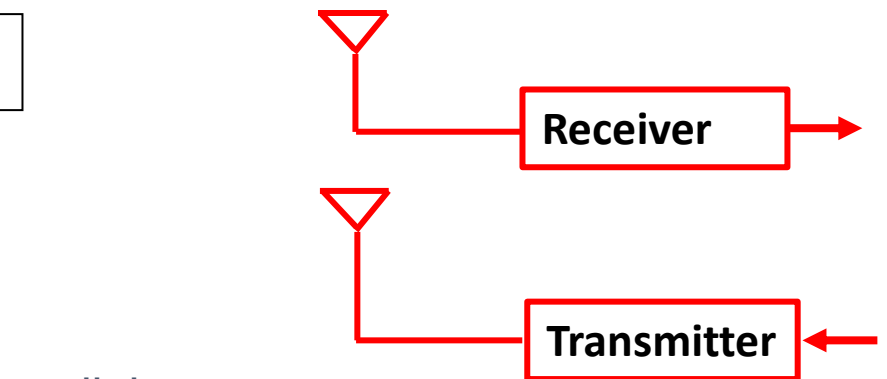
1. Uplink and downlink are separated in frequency
2. Gap of 3 slots in uplink and downlink slots



So the MS does not have to Transmit and Receive at the same time instance!



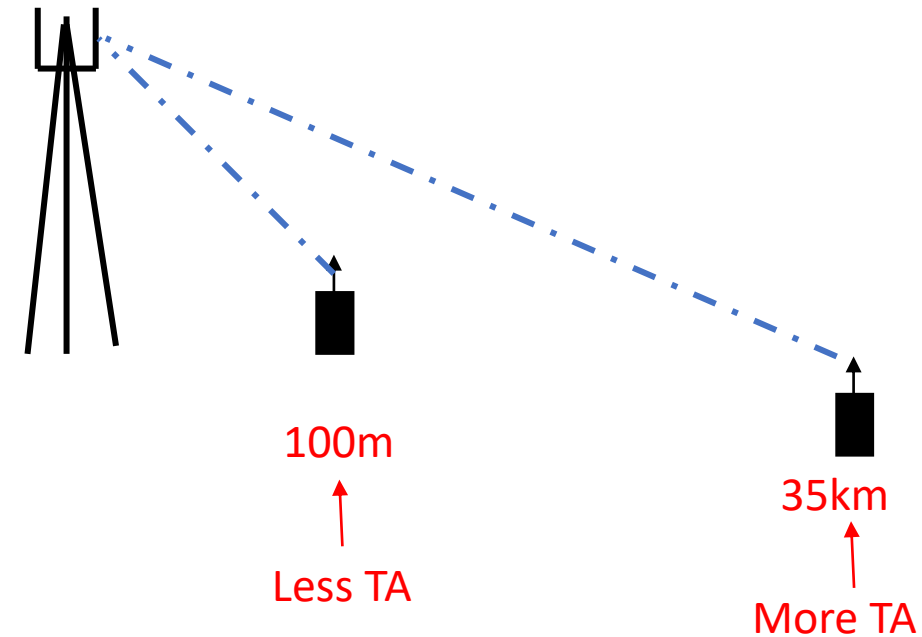
(a) Mobile station TRX



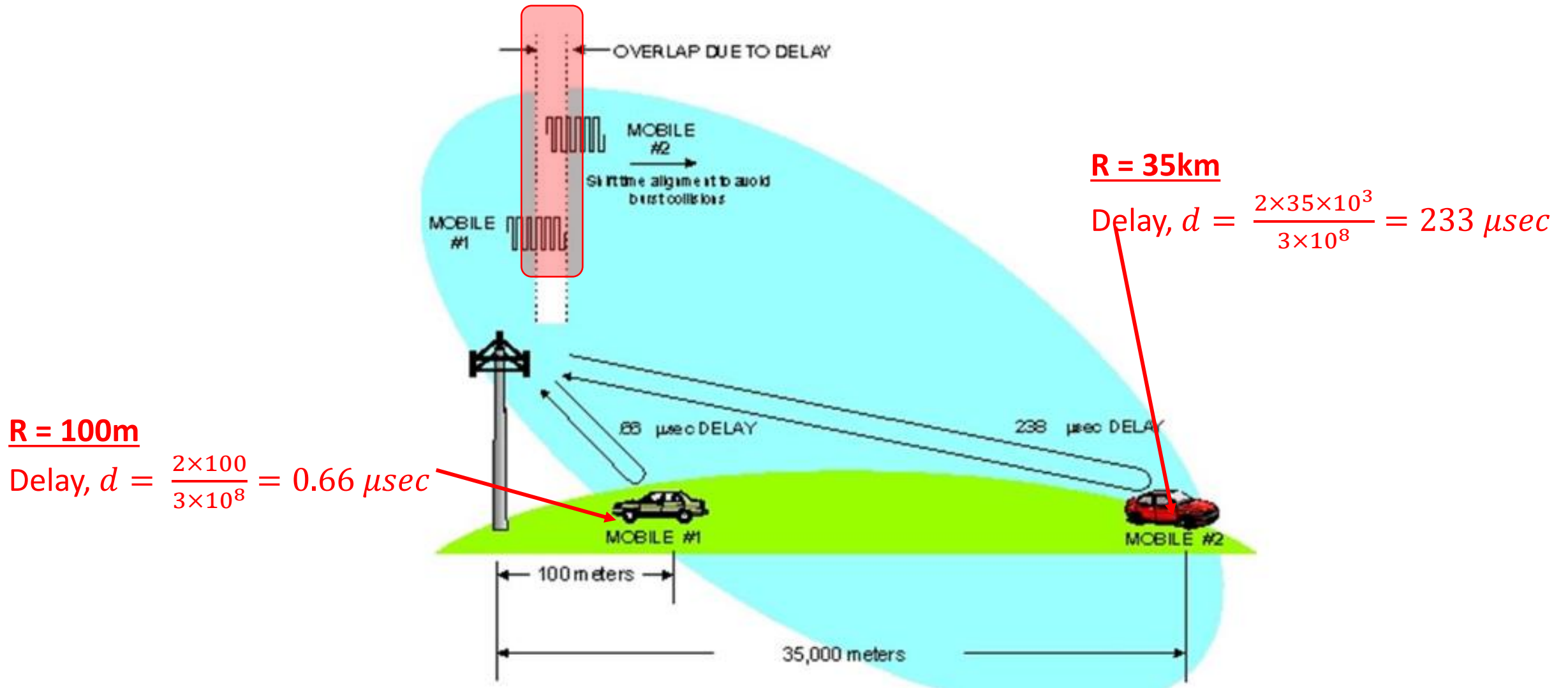
(a) Base station TRX

WHAT IS TIMING ADVANCE?

- GSM TDM requires that each user transmits periodically for less than one-eighth of the time within one of the eight timeslots.
- Since the users are at various distances from the base station and radio waves travel at the finite speed of light, the precise arrival-time within the slot can be used by the base station to determine the distance to the mobile phone.
- To prevent collisions, the time at which the phone is allowed to transmit a burst of traffic within a timeslot is adjusted accordingly to prevent collisions.
- **Timing Advance (TA)** is the variable controlling this adjustment.
- **TA is used to compensate the propagation delay of transmission due to distance between MS and BTS.**



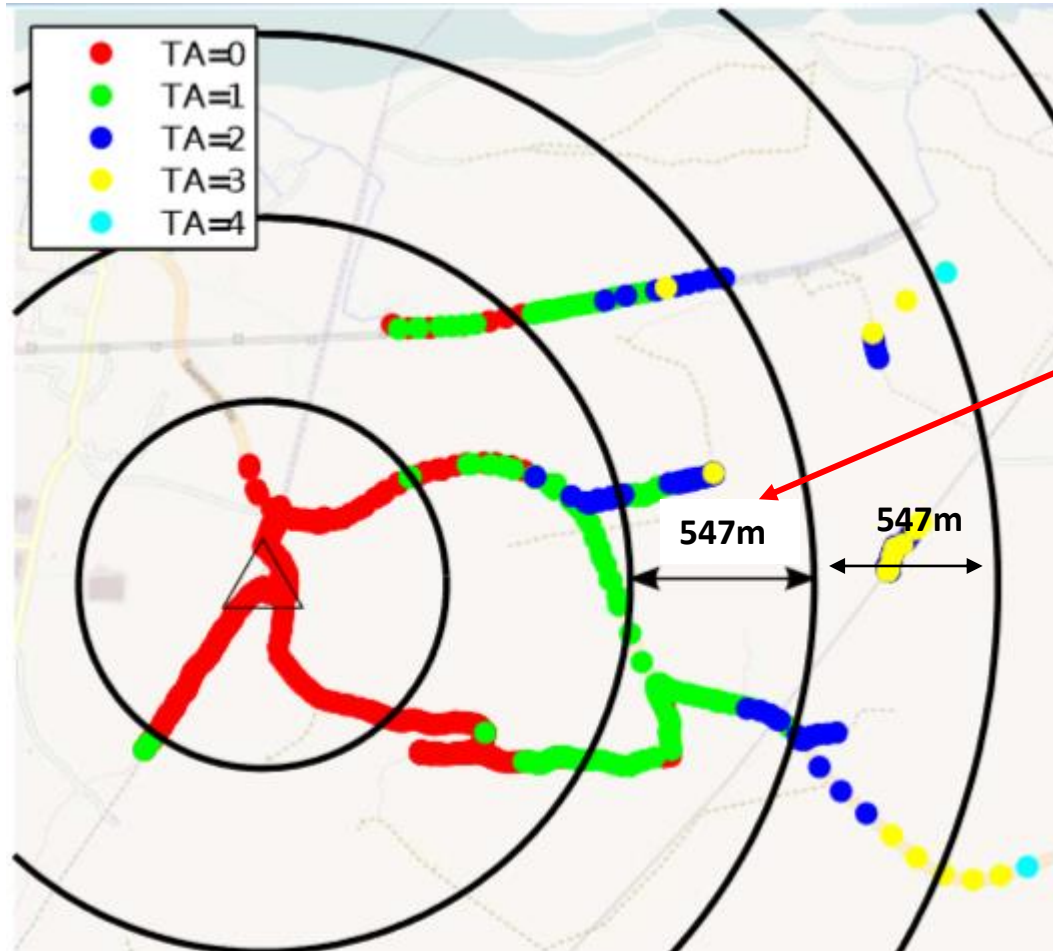
TIMING ADVANCE – THE CONCEPT



WHAT IS TIMING ADVANCE?

1. If the MS moves away from BTS during calling, the signal from BTS to MS will be delayed, so will the signal from MS to BTS.
2. If the delay is too long, the signal in one timeslot from MS cannot be correctly decoded, and this timeslot may even overlap with the timeslot of the next signal from other MS, leading to inter-timeslot interference.
3. Therefore, the report header carries the delay value measured by MS.
4. BTS monitors the arrive time of call and send command to MS every 480 ms, prompting MS to use a specified timing advance (TA) value.

TIME ADVANCE ZONES



Distance between TA zones

$$d = \frac{35 \times 10^3}{64} = 547m$$

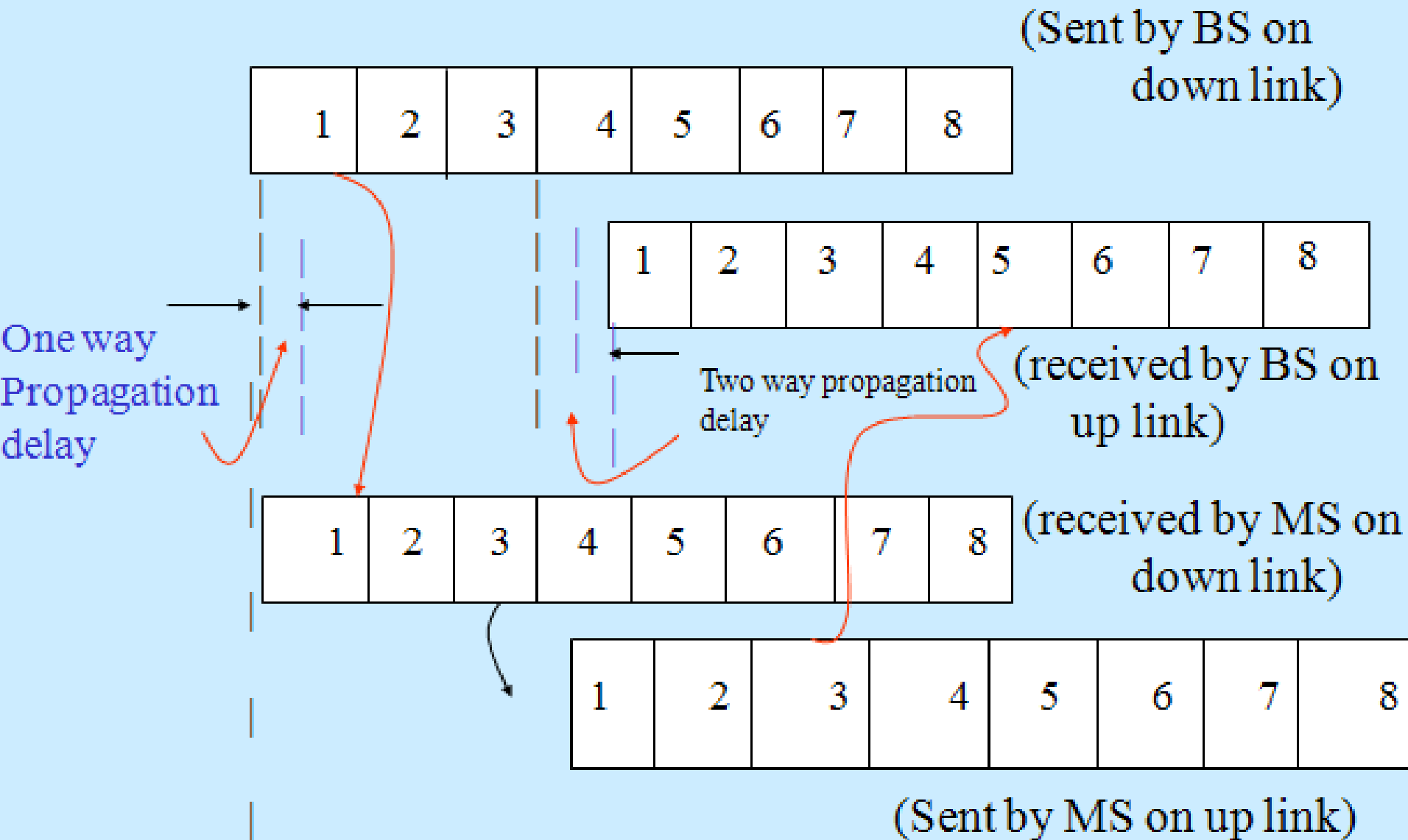
SUMMARY - ADAPTIVE FRAME SYNCHRONIZATION

MS advances its burst transmission by a time corresponding to round trip time.

- The delay is quantified as a 6 bit number.
=> 64 steps (0-63); each step advances the Timing by one bit duration
i.e $577/156 = 3.7 \mu\text{s}$.
- 64 steps allows compensation over a maximum propagation time of $3.7 \times 64 = 31.5$ bit periods or $3.7 \times 31.5 = 113.5 \mu\text{s}$ (=> a maximum distance of ~ 35 km)

$$d = 3 \times 10^8 \times 113.5 \times 10^{-6} = 34 \times 10^3 \text{ m}$$

Timing Advance : How it works.



MAXIMUM RANGE OF GSM MOBILE STATION

1. GSM uses 6-bits to represent Timing Advance (TA).
2. TA value is therefore limited to the range 0 to 2^6-1 , i.e 0 - 63 or (0 - 233 μ s).
3. Therefore, the maximum coverage distance of the GSM is calculation is as follows:

$$R = \frac{1}{2} (t_b N_b c)$$

where

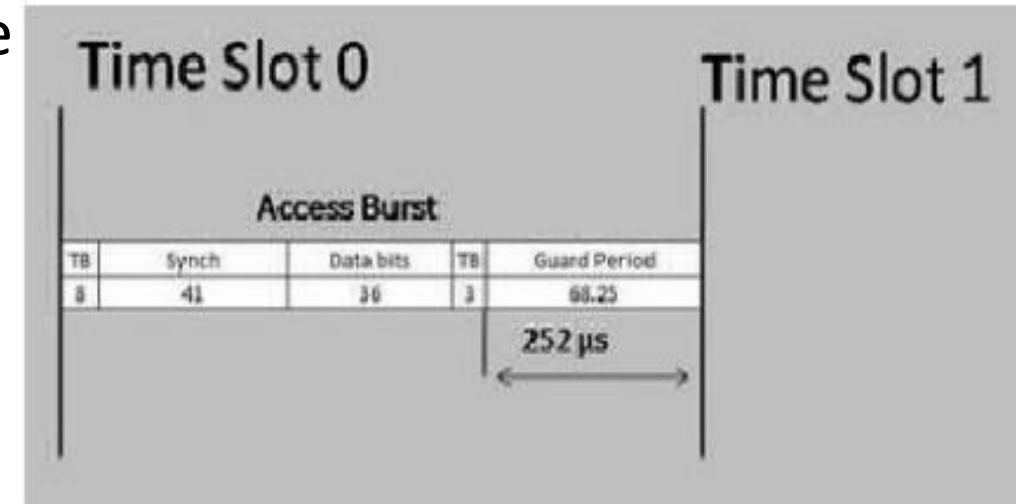
$t_b = 3.7 \mu\text{s/bit}$ is the duration per bit
($1/(270.833 \times 10^3)$)

$N_b = 63\text{bit}$ is the maximum bit for time coordination
(guard band)

c is the speed of light

Substituting we get

$$R = \frac{1}{2} (3.7 \times 10^{-6} \times 63 \times 3 \times 10^8) = 35 \text{ kms}$$



METHOD 2 - PROPAGATION DELAY(1)

- If an access burst has a guard period of 68.25 bits this results in a maximum delay time of approximately $252\mu\text{s}$ ($3.69\mu\text{s} \times 68.25$ bits).
- This means that a signal from the MS could arrive up to $252\mu\text{s}$ after it is expected and it would not interfere with the next time slot.



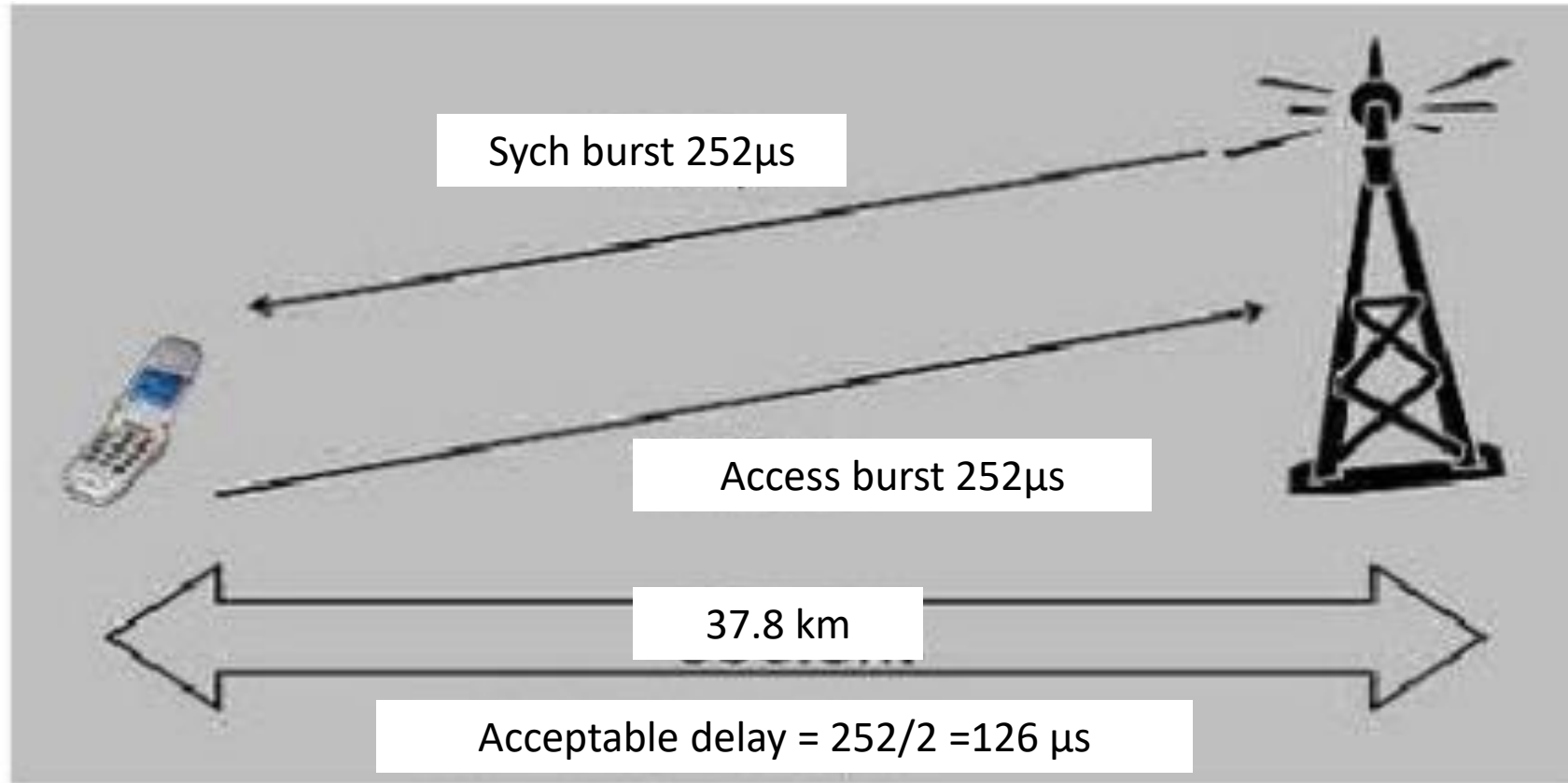
METHOD 2 - PROPAGATION DELAY (2)

- The next step is to calculate how far away a mobile station would have to be for a radio wave to take 252μs to arrive at the BTS.

$$R = c \times t = 3 \times 10^8 \times 252 \times 10^{-6} = 75.6 \text{ km}$$

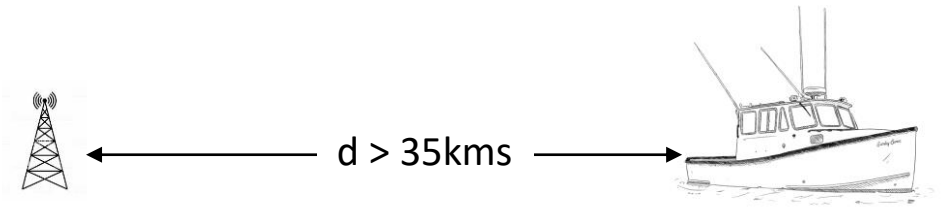
- But we must take into account that the MS synchronizes with the signal it receives from the BTS.
- We must account for the time it takes for the synchronization signal to travel from the BTS to the MS.

METHOD 2 - PROPAGATION DELAY (3)



INCREASING GSM RANGE

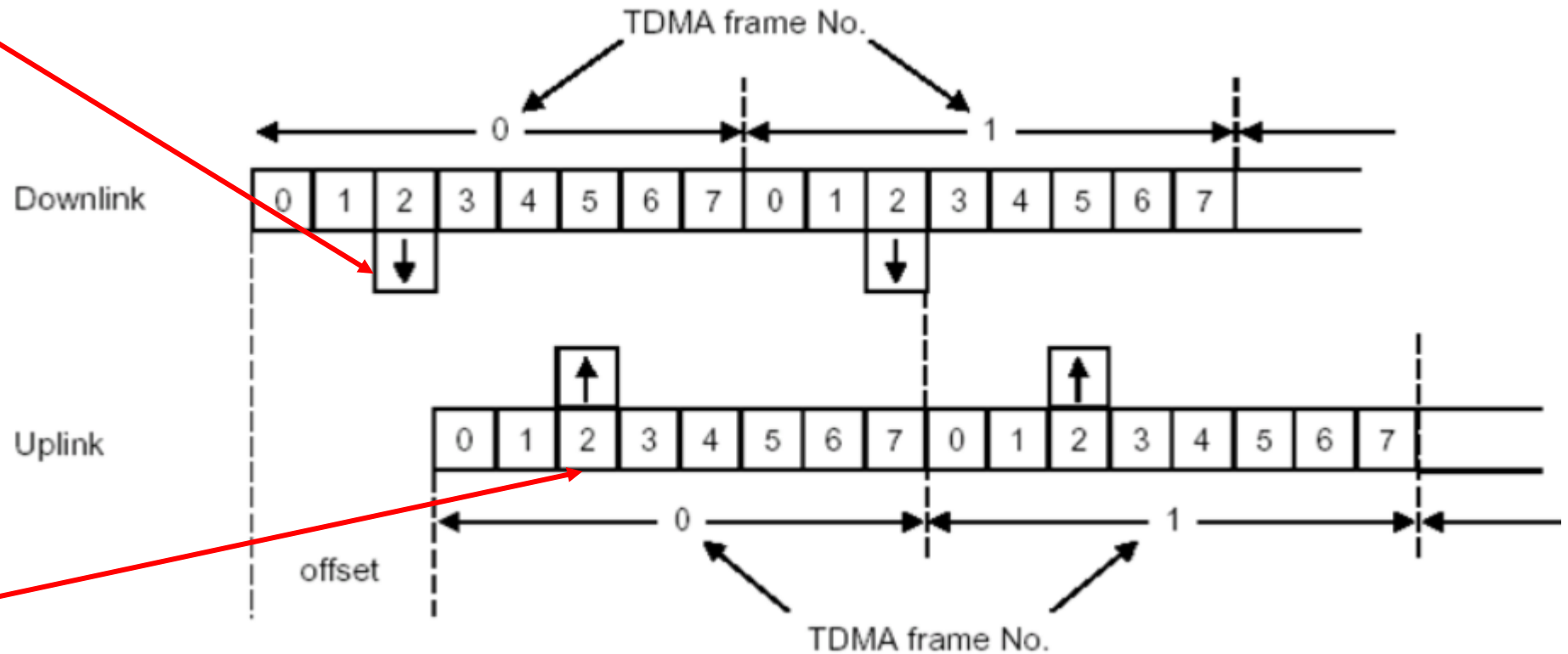
- Sometimes a greater coverage area is required, such as in coastal areas.
- Then, the number of channels that each TRX contains must be reduced in the extended cell.
- The method is to bind odd and even timeslots, so there are only four channels (0/1, 2/3, 4/5, and 6/7) for each TDMA frame in extended cell.



GSM UPLINK & DOWNLINK TIME SLOT SEQUENCE

Downlink

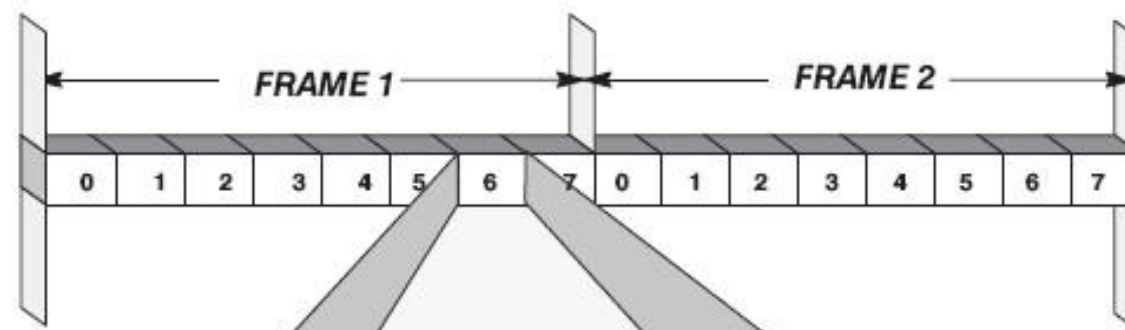
MS receives data on time slot 2



Uplink

MS transmits data on time slot 2 with appropriate timing advance

GSM NORMAL BURST

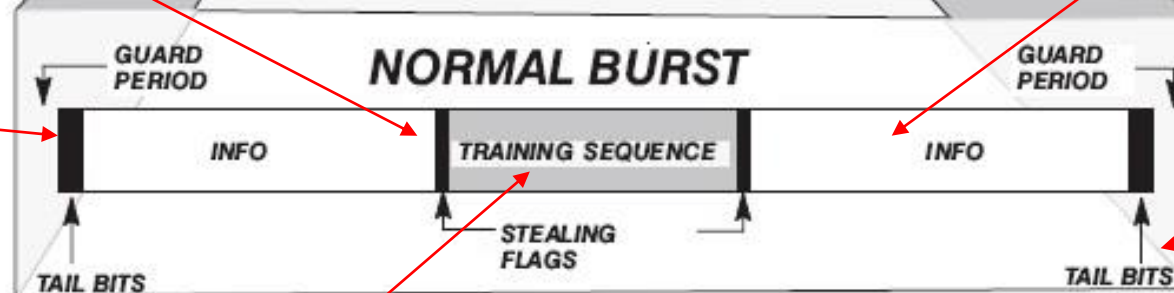


Stealing flags

set when a traffic channel burst has been “stolen” by a FACCH.

Guard Period

Timeslot is 0.577 ms long, whereas the burst is only 0.546 ms long. A guard period of 0.031 ms is provided.



INFO

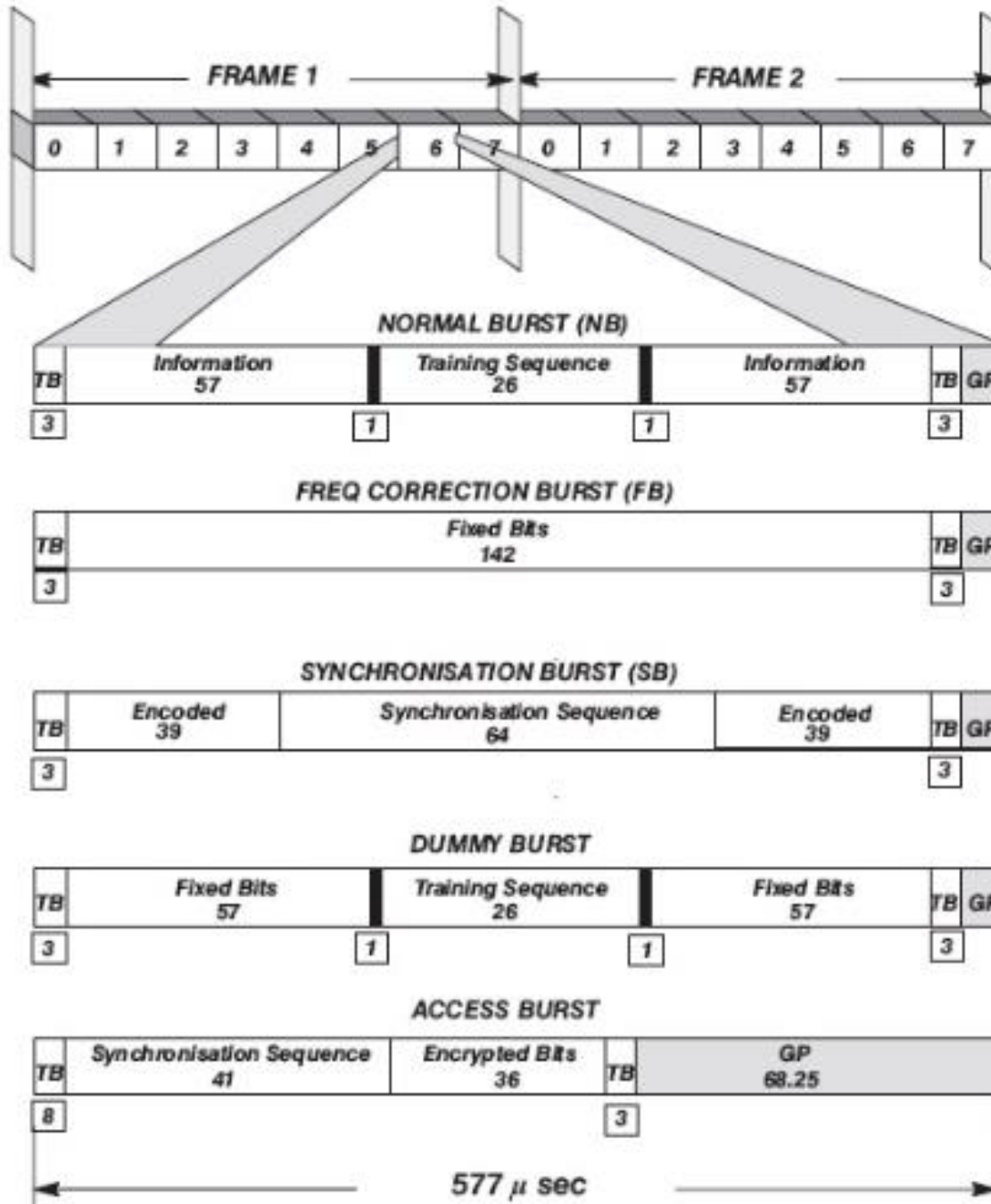
Fields holding data or control information

Trail bits

Used to indicate the beginning and end of the burst.

Training sequence

26 bit sequence used by the receiver's equalizer to estimate the transfer characteristic of the physical path between the BTS and the MS.



Normal burst

Carries traffic channels and all types of control channels.

Frequency Correction Burst

carries FCCH downlink to correct the frequency of the MS's local oscillator, locking it to that of the BTS.

Synchronization Burst

Used for synchronizing the timing of the MS to that of the BTS.

Dummy Burst

Used when there is no information to be carried on the unused timeslots of the BCCH Carrier (downlink only).

Access Burst

Used by the MS when BTS does not know the location of the MS and therefore the timing of the message from the MS is unknown. (uplink only)