EE 484

TDMA Notes

Reference: R.M. Gagliardi, *Introduction to Communications Engineering*, 2nd ed., Wiley, 1988.

In a TDMA system uplink carriers are separated in time rather than frequency. Each carrier is prescribed a time interval to transmit to the satellite. Thus each carrier can use the same carrier frequency and use the entire satellite bandwidth during its interval. Since no other carriers use the satellite during this interval no intermodulation or carrier suppression occurs and the satellite amplifier can be operated in saturation. However, the entire TDMA system requires each plane to be properly synchronized so that each can transmit to the satellite only during its assigned interval. A plane wishing to receive a particular transmission from the satellite must gate in at the appropriate time interval.

The total transmission time must be shared by all users. Thus, the time intervals should be relatively short and repeated at regular intervals. This type of operation is most conducive to digital operation. This then requires all receivers to obtain decoder synchronization for slot timing. For phase-coherent decoding, decoder synchronization requires establishing both a coherent phase reference and a coherent bit timing clock. Also, word synchronization may be needed to separate words that occur during a slot.

If slots are τ seconds then a given plane uses the satellite τ seconds during a T_f second frame. Ideally, all carriers operate at the same data rate. A TDMA frame is divided into slots. Each slot interval is divided into a preamble time and a data transmission time. The preamble time is used to send a synchronization waveform. The preamble typically contains a guard time (to allow for errors in slot timing), a phase referencing and bit timing interval (to allow a phase-coherent decoder to establish carrier and bit synchronization) and a unique code word (to allow for word synchronization).

If a slot contains P preamble bits and D data bits, then

$$\eta = \frac{P}{D+P}$$

is the overhead of the slot preamble. Typically, $\eta \leq 0.10$ or 10%. In order for the satellite to transmit during each slot, it must operate at a bit rate of

$$R_s = \frac{D+P}{\tau} \text{ bps.}$$

Thus, each uplink carrier utilizing one slot per frame sends D bits every frame time which yields a data rate of

$$R_b = \frac{D}{T_f} \text{ bps.}$$

Therefore, the total number of slots per frame is

$$K = \frac{T_f}{\tau} = \frac{D/R_b}{(D+P)/R_s} = (1-\eta)\frac{R_s}{R_b}.$$

We see that the desired overhead and bit rates limit the number of TDMA users.

Decoding performance of the slot bits depends on the transponded E_b/N_0, The receiver decoder E_b/N_0 is

$$\frac{E_b}{N_0} = \left[(\text{CNR}_u)^{-1} + \left(\frac{P_T L}{N_{0d} R_s}\right)^{-1}\right]^{-1}$$

where L is the combined downlink power losses and gains from the satellite amplifier output to the receiver input, N_{0d} is the receiver noise spectral level, CNR_u is the uplink CNR in the satellite bit rate bandwidth R_s and P_T is the maximum saturation power of the satellite amplifier.If an $E_b/N_0 = \gamma$ is required to decode the slot bits for the spec probability of error then

$$P_T = \frac{\gamma R_s N_{0d}}{L}.$$

Thus, a TDMA system may be satellite power limited (producing a slot decoding probability of error with a satellite bit rate R_s) or may be satellite bit rate limited in supporting the desired number of users.