Time Division Multiple Access

- At the receiving Earth station, bursts from Earth stations are received in sequence, selected for recovery if addressed for this station, and then spread back out in time in an output expansion buffer.
- It is vital that all bursts be synchronized to prevent overlap at the satellite; this is accomplished either with the synchronization burst (as shown) or externally using a separate carrier.
- Individual time slots may be pre-assigned to particular stations or provided as a reservation, with both actions under control by a master station.
- For traffic that requires consistent or constant timing (e.g., voice and TV), the time slots repeat at a constant rate.

Time Division Multiple Access

- Computer data and other forms of packetized information can use dynamic assignment of bursts in a scheme much like a DAMA network.
- There is an adaptation for data, called ALOHA, that uses burst transmission but eliminates the assignment function of a master control.
- ALOHA is a powerful technique for low cost data networks that need minimum response time. Throughput must be less than 20% if the bursts come from stations that are completely uncoordinated because there is the potential for time overlap (called a collision).

Time Division Multiple Access

- The most common implementation of ALOHA employs a hub station that receives all of these bursts and provides a positive acknowledgement to the sender if the particular burst is good.
- If the sending station does not receive acknowledgment within a set “time window,” the packet is re-sent after a randomly selected period is added to prevent another collision.
- This combined process of the window plus added random wait introduces time delay, but only in the case of a collision.
- Throughput greater than 20% brings a high percentage of collisions and resulting retransmissions, introducing delay that is unacceptable to the application.

Time Division Multiple Access

- An optimally and fully loaded TDMA network can achieve 90% throughput, the only reductions required for guard time between bursts and other burst overhead for synchronization and network management.
- The corresponding time delay is approximately equal to one-half of the frame time, which is proportional to the number of stations sharing the same channel.
- This is because each station must wait its turn to use the shared channel.
- ALOHA, on the other hand, allows stations to transmit immediately upon need. Time delay is minimum, except when you consider the effect of collisions and the resulting retransmission times

Time Division Multiple Access

- TDMA is a good fit for all forms of digital communications and should be considered as one option during the design of a satellite application.
- The complexity of maintaining synchronization and control has been overcome through miniaturization of the electronics and by way of improvements in network management systems.
- With the rapid introduction of TDMA in terrestrial radio networks like the GSM standard, we will see greater economies of scale and corresponding price reductions in satellite TDMA equipment.

Code Division Multiple Access

- CDMA, also called spread spectrum communication, differs from FDMA and TDMA because it allows users to literally transmit on top of each other.
- This feature has allowed CDMA to gain attention in commercial satellite communication.
- It was originally developed for use in military satellite communication where its inherent anti-jam and security features are highly desirable.
- CDMA was adopted in cellular mobile telephone as an interference-tolerant communication technology that increases capacity above analog systems.

Code Division Multiple Access

- It has not been proven that CDMA is universally superior as this depends on the specific requirements.
- For example, an effective CDMA system requires contiguous bandwidth equal to at least the spread bandwidth.
- Two forms of CDMA are applied in practice:

  (1) direct sequence spread spectrum (DSSS) and

  (2) frequency hopping spread spectrum (FHSS).
- FHSS has been used by the OmniTracs and Eutel-Tracs mobile messaging systems for more than 10 years now, and only recently has it been applied in the consumer's commercial world in the form of the Bluetooth wireless LAN standard. However, most CDMA applications over commercial satellites employ DSSS (as do the cellular networks developed by Qualcomm).

Code Division Multiple Access

- Consider the following summary of the features of spread spectrum technology (whether DSSS or FHSS):
  - Simplified multiple access: no requirement for coordination among users;
  - Selective addressing capability if each station has a unique chip code sequence—provides authentication: alternatively, a common code may still perform the CDMA function adequately since the probability of stations happening to be in synch is approximately $1/n$;
  - Relative security from eavesdroppers: the low spread power and relatively fast direct sequence modulation by the pseudorandom code make detection difficult;
  - Interference rejection: the spread-spectrum receiver treats the other DSSS signals as thermal noise and suppresses narrowband interference.

Code Division Multiple Access

- A typical CDMA receiver must carry out the following functions in order to acquire the signal, maintain synchronization, and reliably recover the data:
  - Synchronization with the incoming code through the technique of correlation detection;
  - De-spreading of the carrier;
  - Tracking the spreading signal to maintain synchronization;
  - Demodulation of the basic data stream;
  - Timing and bit detection;
  - Forward error correction to reduce the effective error rate;

Code Division Multiple Access

- The first three functions are needed to extract the signal from the clutter of noise and other signals.
- The processes of demodulation, bit timing and detection, and FEC are standard for a digital receiver, regardless of the multiple access method.

Multiple Access Summary

- The bottom line in multiple access is that there is no single system that provides a universal answer.
- FDMA, TDMA, and CDMA will each continue to have a place in building the applications of the future.
- They can all be applied to digital communications and satellite links.
- When a specific application is considered, it is recommended to perform the comparison to make the most intelligent selection.

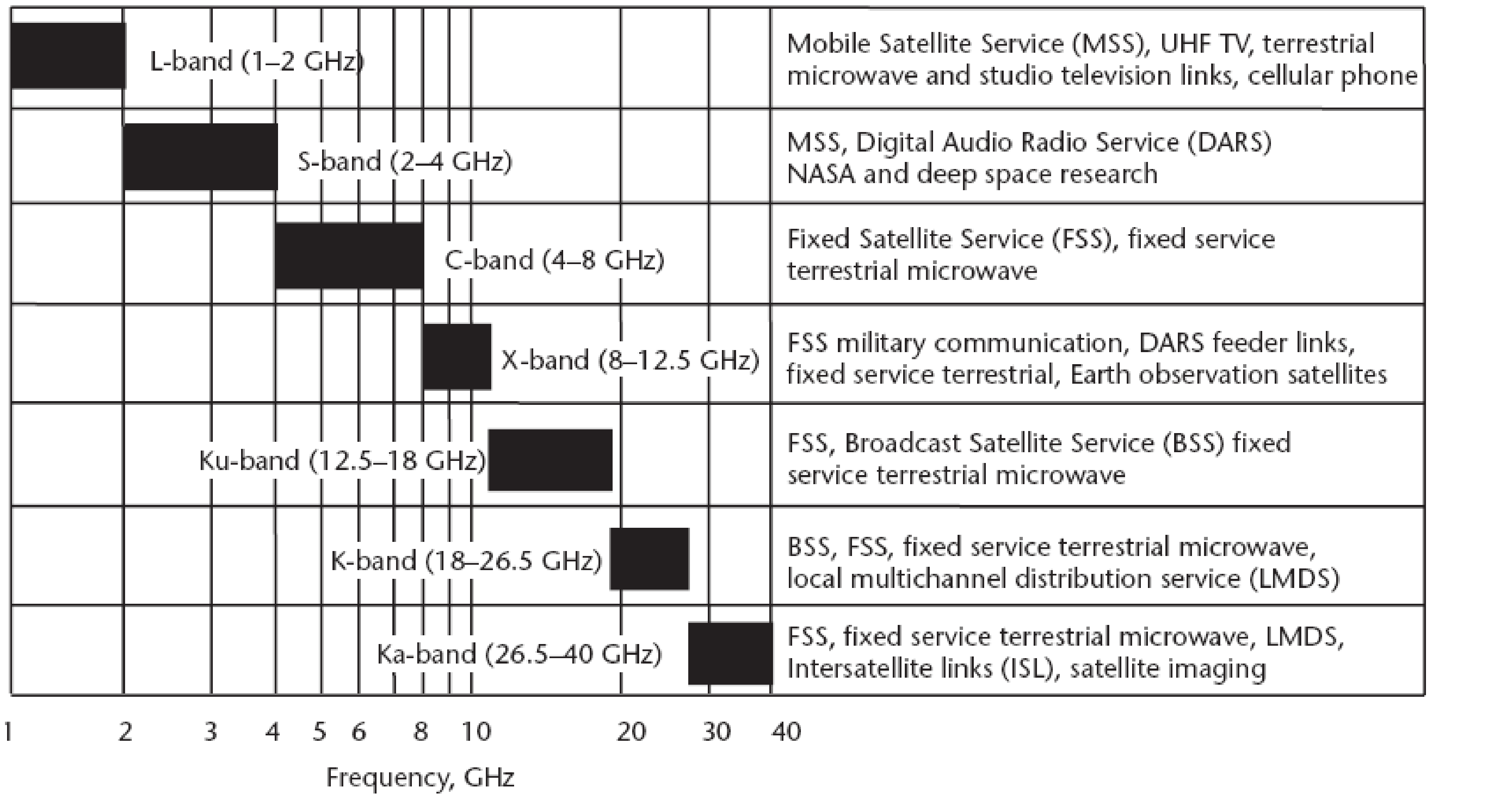
Frequency Band Trade-Offs

- Satellite communication is a form of radio or wireless communication and therefore must compete with other existing and potential uses of the radio spectrum.
- During the initial 10 years of development of these applications, there appeared to be more or less ample bandwidth, limited only by what was physically or economically justified by the rather small and low powered satellites of the time.
- In later years, as satellites grew in capability, the allocation of spectrum has become a domestic and international battlefield as service providers fight among themselves, joined by their respective governments when the battle extends across borders.
- So, we must consider all of the factors when selecting a band for a particular application.

Frequency Band Trade-Offs

- The most attractive portion of the radio spectrum for satellite communication lies between 1 and 30 GHz.
- The relationship of frequency, bandwidth, and application are shown in Figure
- The scale along the *x*-axis is logarithmic in order to show all of the satellite bands; however, observe that the bandwidth available for applications increases in real terms as one moves toward the right (i.e., frequencies above 3 GHz).
- Also, the precise amount of spectrum that is available for services in a given region or country is usually less than indicates.

Frequency Band Trade-Offs



Frequency Band Trade-Offs

- The use of letters probably dates back to World War II as a form of shorthand and simple code for developers of early microwave hardware.
- Two band designation systems are in use: adjectival (meaning the bands are identified by the following adjectives) and letter (which are codes to distinguish bands commonly used in space communications and radar).

Frequency Band Trade-Offs

- Adjectival band designations, frequency in Gigahertz:

  Very high frequency (VHF): 0.03–0.3;

  Ultra high frequency (UHF): 0.3–3;

  Super high frequency (SHF): 3–30;

  Extremely high frequency (EHF): 30–300.

Frequency Band Trade-Offs

- Letter band designations, frequency in Gigahertz:
  - L: 1.0–2.0;
  - S: 2.0–4.0;
  - C: 4.0–8.0;
  - X: 8–12;
  - Ku: 12–18;
  - Ka: 18–40;
  - Q: 40–60;
  - V: 60–75;

Frequency Band Trade-Offs

- Today, the letter designations continue to be the popular buzzwords that identify band segments that have commercial application in satellite communications.
- The international regulatory process, maintained by the ITU, does not consider these letters but rather uses band allocations and service descriptors .

Frequency Band Trade-Offs

Fixed Satellite Service (FSS): between Earth stations at given positions, when one or more satellites are used; the given position may be a specified fixed point or any fixed point within specified areas; in some cases this service includes satellite-to-satellite links, which may also be operated in the inter-satellite service; the FSS may also include feeder links for other services.

Mobile Satellite Service (MSS): between mobile Earth stations and one or more space stations (including multiple satellites using inter-satellite links). This service may also include feeder links necessary for its operation.

Broadcasting Satellite Service (BSS): A service in which signals transmitted or retransmitted by space stations are intended for direct reception by the general public. In the BSS, the term “direct reception” shall encompass both individual reception and community reception.

Inter-satellite Link (ISL): A service providing links between satellites.

Frequency Band Trade-Offs

- The lower the band in frequency, the better the propagation characteristics. This is countered by the second general principle, which is that the higher the band, the more bandwidth that is available. The MSS is allocated to the L- and S-bands, where propagation is most forgiving.
- Yet, the bandwidth available between 1 and 2.5 GHz, where MSS applications are authorized, must be shared not only among GEO and non-GEO applications, but with all kinds of mobile radio, fixed wireless, broadcast, and point-to-point services as well.
- The competition is keen for this spectrum due to its excellent space and terrestrial propagation characteristics. The rollout of wireless services like cellular radiotelephone, PCS, wireless LANs, and 3G may conflict with advancing GEO and non-GEO MSS systems.
- .

- Generally, government users in North America and Europe, particularly in the military services, have employed selected bands such as S, X, and Ka to isolate themselves from commercial applications.
- However, this segregation has disappeared as government users discover the features and attractive prices that commercial systems may offer