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Satellite Transponders

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At the end I am paying regards to my parents, who help me on every stage of my life where ever I need, and they pick me up about studies and in all meters of life, and it is only because of their prayers that I am completing my degree. I whish they always be happy.

ABSTRACT

In daily life satellite communication has a great importance and used in every important field like in official work, army field and the field of science.

A Satellite Communication System can take many different forms. As associated antennas and satellite transponder forms the primary portion of the communication as a sub system on a communication satellite. These transponders differ from conventional microwave and ordinary communication systems, which access the satellite simultaneously at nearly the same instant from widely different points on earth. So we can say multiple carriers arrive at, and must be relayed by, the satellite Transponder. And its opens the new sought of light on human.

In chapters 1 of satellite communication I briefly describes the major elements and types of communication devices, systems, and controlling of different kind of antennas and transponders. In chapter 2 there is a discussion about multi channel transponder, some of the advantages of transponder canalization, typical frequency plans and potential advantages, of processing transponders. Frequency Division Multiple Access (FDMA) protocols have the potential to provide simple but effective broadcast bus communications for embedded systems is described in chapter 3. However, bus-master based protocols such as TDMA can be undesirable in practice because the bus master node constitutes single-point failure vulnerability and adds to system expense. It presents the FDMA protocol, which eliminates the need for having a bus master through the use of a nondestructive jamming signal for frame synchronization. Which can be critical for low-cost implementations. FDMA reaps the benefits of protocols without suffering the reliability and system complexity drawbacks of FDMA methods.

Chapter 4 covers the detail effects of the TDMA multiple access techniques. And also describe the fundamental properties of frequency division multiple access (FMDA). Multiple from the same and different earth terminals are transmitted on carriers at different RF center frequencies. This detailed changes the transponder on different type of multiple-access techniques like Jam-TDMA (J-TDMA) protocol, which eliminates the need for having a bus In it a detailed description of the J-TDMA protocol and show how to minimize the effects of speed differences among nodes on TDMA systems.

INTRODUCTION

Motivation is the electronic communication between the five senses of humans: Ear, Eyes, Nose, Skin, and Tongue. Currently, we are only using two senses to communicate information. Modern living standards demand that we have access to a reliable, economical and efficient means communication, which may be optionally mobile.

For intercontinental communication, satellite radio links become a commercially attractive proposition. Space communication showed phenomenal growth in the 1970s. And it will continue to grow for some years to come. The growth has been so rapid that there is now danger of overcrowding the geo-stationary orbit.

Satellites must have a continuous source of electrical power--24 hours a day, 365 days a year. The two most common power sources are high performance batteries and solar cells. Solar cells are an excellent power source for satellites. They are lightweight, resilient, and over the years have been steadily improving their efficiency in converting solar energy into electricity. Satellite communication became a possibility when it was realized that a satellite orbiting at a distance of 36000Km from the Earth would be geo-stationary.

Satellite transponders, which are built and tested over many months under extremely rigorous conditions, are designed to function well beyond the normal lifetime of a spacecraft. That's why most geo-synchronous birds can continue to provide service for some customers even after they exhaust their fuel supply and can no longer maintain their stationary orbital position. Communications networks require a broad understanding of its segments, their costs, advantages and interfaces with other segments within the network. Further more, to avoid the chaos, we want to our earth stations to gain access to the transponders capacity allocated to them in an orderly session. This called multiple accesses. The most commonly used multiple schemes are:

1. Frequency Division Multiple Access (FDMA).
2. Time Division Multiple Access (TDMA).

The FDMA class of signals includes many variations in the number and bandwidth of carriers transmitted by a given earth station. For example, we might transmit only one carrier per earth station, where the data to all receive terminals is multiplexed on that single carrier. Alternatively, each terminal might transmit separate carriers for each receive earth terminal being addressed. This latter approach has the advantage that it requires the receive earth terminal to demodulate only the data intended for it, but this technique may not have any power or efficiency advantage. Finally, one can provide a separate carrier for each voice channel.

In 1983 the Federal Communications Commission approved a frequency band for domestic direct broadcast satellite services (DBS) to provide direct-to-home television: an uplink frequency of 173 to 17.8 GHz and a downlink frequency of 12.2 to 12.7 GHz.

The DBS downlink portion of the Ku band is adjacent to the 11.7-to 12.2-GHz downlink frequency of the FSS portion of the Ku band. High-power direct broadcast satellites have many characteristics similar to those of communications satellites except that the DBS downlink radiated power is about 10 dB more per transponder.

All types of modulation can be used for both the sub carrier oscillators and the prime carrier. The transmission system for frequency division multiplex systems is designated by first giving the modulation for the sub carriers and then the prime carrier. Thus FM/AM would indicate a frequency-division multiplex system in which the sub carriers are frequency modulated and the prime carrier is amplitude modulated by the composite sub carrier signal.

The pulse-amplitude waveform may take several forms as can be seen below. The principle difference lies in the duty cycle of the pulse. In the figure 3.9 on the right the top diagram shows a 100% duty cycle system while the lower diagram shows a 50% duty cycle system signals.

The simplicity of TDMA lends itself well to embedded systems with limited hardware resources at each node. TDMA also avoids many subtle failure modes associated with more complex protocols, such as duplicate tokens on token bus systems. TDMA can have low protocol overhead if the multiplexed time slices are well balanced with respect to node workloads. And, TDMA does not require collision detection circuitry, which can be difficult or costly to implement in embedded systems.

Burst timing if the unique word belongs to the traffic burst. The position of every burst in the frame is defined with respect to the receive frame timing, and the position of every sub burst in a traffic burst is defined with respect to the burst's receive burst timing. It

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1. INTRODUCTION TO COMMUNICATION

Communication, the process of transmitting and receiving ideas, information, and messages. The rapid transmission of information over long distances and ready access to information have become conspicuous and important features of human society, especially in the past 150 years, and in the past two decades, increasingly so. Communication between two or more than two people is an outgrowth of methods developed over communication. Communication is essential for the growth of mankind e.g. the use of paper to communicate ideas was and still is, responsible for the growth of Science and Technology. Communication equipment, which is a part of our daily life, are responsible for the acceleration of this process, e.g. Photocopying machine, telephone, radio, television, fax machine, satellite, cellular phone, computers, CD-RW, Internet. Motivation is the electronic communication between the five senses of humans: Ear, Eyes, Nose, Skin, and Tongue. Currently, we are only using two senses to communicate information. Modern living standards demand that we have access to a reliable, economical and efficient means communication, which may be optionally mobile. Almost an endless list of information handling systems developed worldwide.

Typically, signals are transferred over wires, through optical fibers or through space using electromagnetic waves. We live in a world of networks, which avoids dedicated connections, allows the sharing of resources, promotes the exchange of information around the world, etc.

The developments are:

1. Telephone number per person
2. Wireless networks - schools, companies, etc.
3. Integration of services & traffic (data, voice, graphics, and video): Home banking, bills.
4. The electronic communication of "scent", "taste" and "touch".

Goals can be counted as:

1. Minimize the time to access information
2. Minimize location constraints to access information
3. Maximize the simultaneous access to information
4. Make use of all five senses

1.1 Satellite Communication

All major satellite operators, INTELSAT, EUTELSAT, INMARSAT, etc. mostly use the geo-stationary orbit (GEO). In this orbit, the satellite appears to be stationary when viewed from the Earth. Thus, the Earth station antennas point in a fixed direction as in figure 1.1.

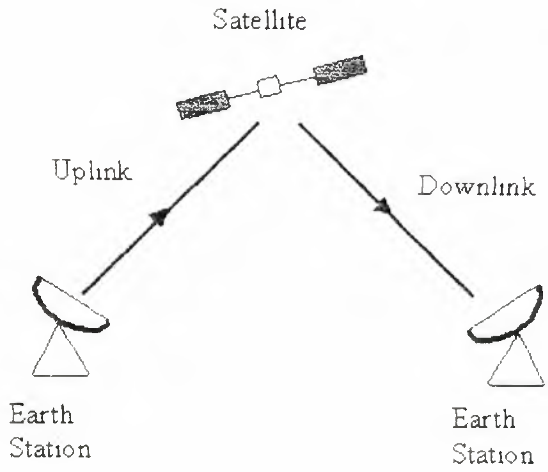


Figure 1.1: Satellite position

In the GEO orbit (as in figure 1.2), the satellite is approx. 22,300 miles above the equator.

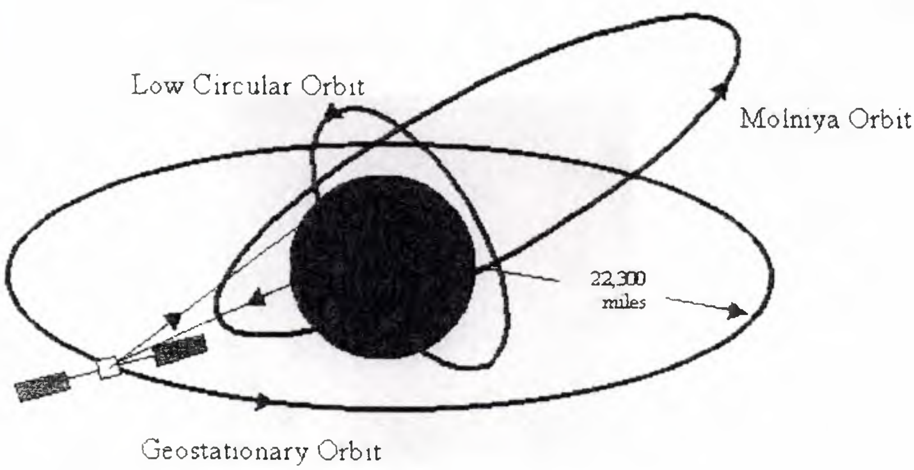


Figure 1.2: An Orbit

Most desired frequency band for satellite communications is 6 GHz on the uplink and 4 GHz on the downlink, referred to as the 6/4 GZ C-band. In this range, cosmic noise is small, and rainfall does not appreciably attenuate the signals. Also, losses due to the ionosphere and atmospheric absorption are small.

Second generation satellites operate using the 14/12 GHz Ku-band. These higher frequencies make it possible to build smaller and less expensive antennas.

Each satellite has a number of transponders (receiver-to-transmitter) aboard to amplify the received signal from the uplink and down-convert the signal for transmission on the downlink. Typically, there are 24 transponders in a satellite. The figure 1.3 below shows the basic components of a single transponder.

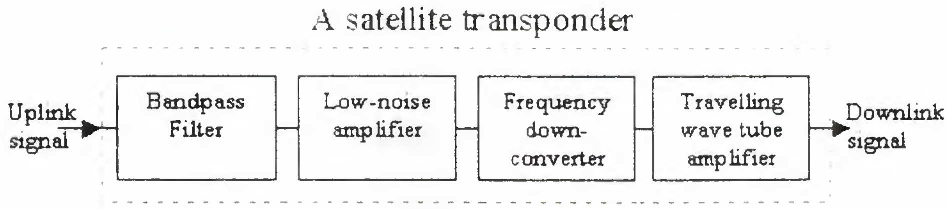


Figure 1.3: Components of a single transponder

For the standard C-band (6/4 GHz) television relay service, each satellite is assigned a total of a 500 MHz bandwidth. A typical satellite has 24 transponders aboard, with each transponder using 36 MHz of the 500 MHz bandwidth assignments. Note that the satellites reuse the same frequency band by having 12 transponders operating with vertically polarized signals and 12 transponders with horizontally polarized signals. The figure 1.4 below shows the sample satellite.

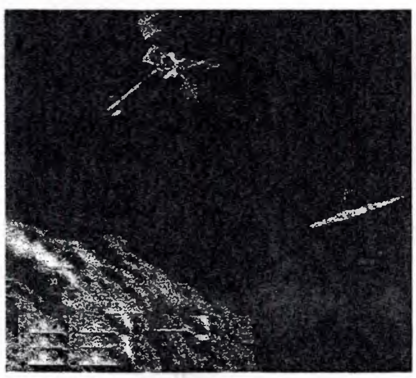


Figure1.4: A sampled satellite

The figure 1.5 below illustrates this for the Galaxy satellites. In particular, the G5 satellite on C-band (because its my favorite). Note that this is analog television in which a single TV channel is frequency modulated onto a 6 GHz carrier. In the near future, such analog systems will be a thing of the past.

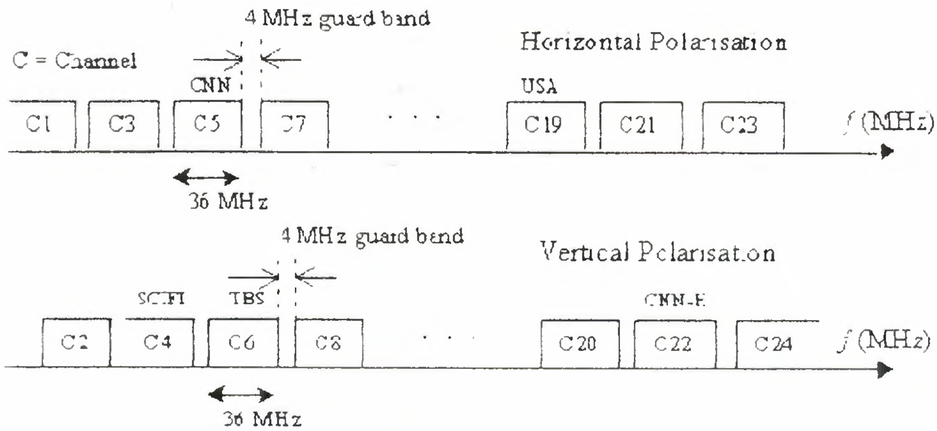


Figure 1.5: Galaxy satellites

High-power satellites, called direct broadcast satellites (DBS), provide TV service directly to the home, which has a small receiving antenna e.g. Direct TV. The base band video signal is sampled, digitized, and compressed by removing redundant samples that occur frame to frame. Satellite communication became a possibility when it was realized that a satellite orbiting at a distance of 36000Km from the Earth would be geo-stationary, i.e. would have an angular orbital velocity equal to the Earth's own orbital velocity. It would thus appear to remain stationary relative to the Earth if placed in an equatorial orbit. This is a consequence of Kepler's law that the period of rotation T of a satellite around the Earth was given by:

$$T = \frac{2\pi r^{3/2}}{\sqrt{(g_s R^2)}}$$

Where r is the orbit radius, R is the Earth's radius and $g_s = 9.81ms^{-2}$ is the acceleration due to gravity at the Earth's surface. As the orbit increases in radius, the angular velocity reduces, until it is coincident with the Earth's at a radius of 36000Km. In principle, three geostationary satellites correctly placed can provide complete coverage of the Earth's surface as in figure 1.6

For intercontinental communication, satellite radio links become a commercially attractive proposition. Space communication showed phenomenal growth in the 1970s.

And it will continue to grow for some years to come. The growth has been so rapid that there is now danger of overcrowding the geostationary orbit.

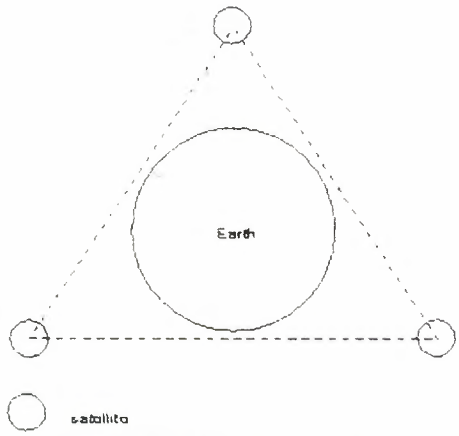


Figure 1.6: Geo-stationary satellites

1.2 Advantages of Satellite Communication

Satellite communication has a number of advantages:

1. The laying and maintenance of intercontinental cable is difficult and expensive.
2. The heavy usage of intercontinental traffic makes the satellite commercially attractive.
3. Satellites can cover large areas of the Earth. This is particularly useful for sparsely populated areas.

Satellite communication is limited by four factors:

1. Technological limitations preventing the deployment of large, high gain antennas on the satellite platform.
2. Over-crowding of available bandwidths due to low antenna gains.
3. The high investment cost and insurance cost associated with significant probability of failure.
4. High atmospheric losses above 30GHz limit carrier frequencies.

1.3 Microwave Antenna

A microwave antenna has two functions. It provides gain (i.e. amplification). It also directs the radiation into confined regions of space: the antenna beam. These properties are largely dependent on the antenna size. For a circular, dish antenna, the gain G is related to the antenna area A by the formula:

$$G = 4\pi A/\lambda^2$$

Where $\lambda$is the wavelength of the transmitted carrier. Thus, large antennas have high gains and narrow beams as shown in figure 1.7.

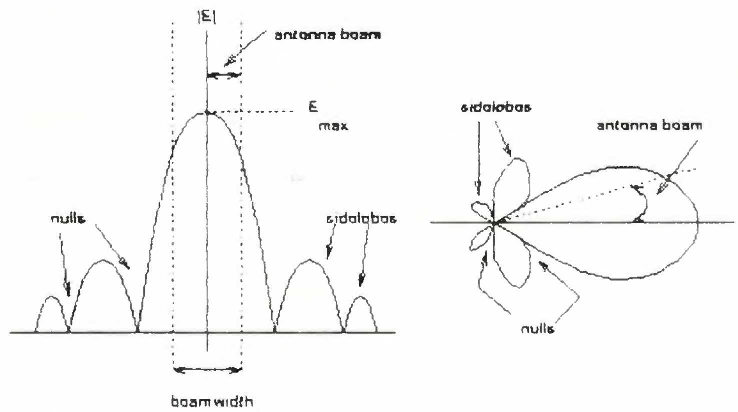


Figure 1.7: A typical antenna beam profile of a dish antenna

The cost of constructing an antenna is a strong function of its size. A rough rule of thumb is the cost is proportional to the diameter cubed. Thus a doubling of the antenna size will result in the satellite cost increasing eight times. As a result, antenna sizes are limited. The limitation in antenna size means that the satellite beam is wide. In order to prevent electromagnetic interference with terrestrial stations, the power radiated by the satellite is limited by international convention. In any event power is severely limited on a satellite platform.

Because the radiated power is low, large receiving antennas are required. The larger the receiver antenna, the larger the antenna gain, and hence the better the receiver SNR. The SNR is a function of the bandwidth, and the atmospheric attenuation. Ground stations close to the poles of the Earth have low elevation look angles, and signals have to pass through a thicker section of atmosphere. The size of receiver antenna is determined by the two requirements; 500MHz receive bandwidth and full capability at $\pm 80^{o}$of latitude. A standard INTELSAT receiver is 30m in diameter. An antenna this large has a very narrow beam, typically 0.01^{o}. A geostationary satellite is not truly stationary; it wanders slightly in the sky. The very narrow beam width of the receiver requires automatic tracking of the satellite, and continuous pointing of the receiver antenna.

The use of satellites for regional communication is possible if there is sufficient demand for traffic. By reducing the range of latitudes down to $\pm 60^{o}$, and reducing the bandwidth down to 50MHz, large reductions in satellite and ground station receiver costs are possible. One such direct-to-user (DTU) system is the Satellite Business System (SBS) covering a range of business and government's users with a demand for high-speed data links in the US. The region is split into areas, roughly coincident with the satellite antenna gain contours, denoting increased cost of receiver technology. It is important to realize that the economies of satellite communication only make this regional communication possible if the system is heavily used as in figure 1.8.

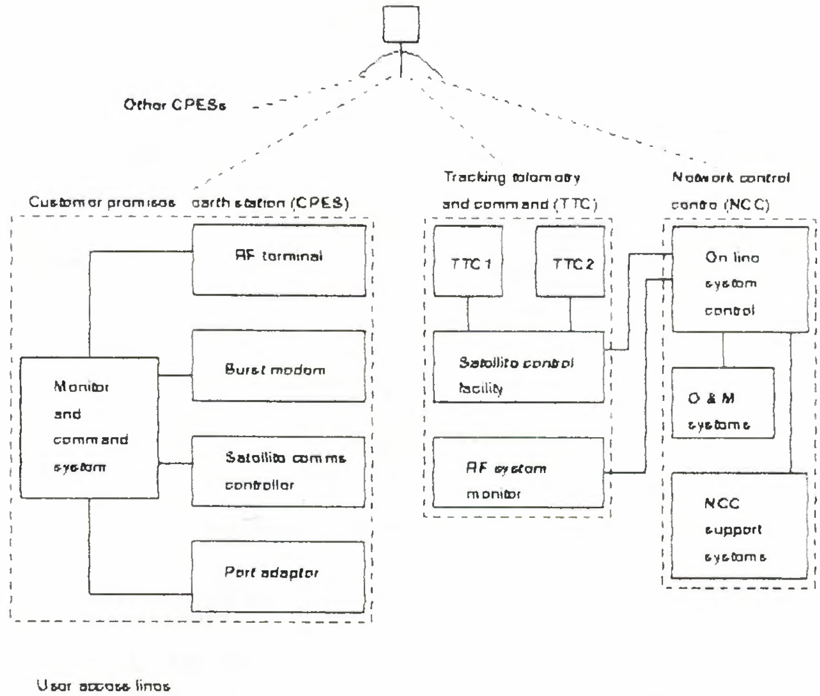


Figure 1.8: The Satellite Business System operational schematic

Improvements in satellite receiver technology have permitted smaller antennas to be used as ground station receivers. However, antennas are reciprocal. They have the same directional characteristics in transmit and receive. The use of low gain, wide beam earth stations for DTU systems have contributed considerably to the bandwidth-overcrowding problem, particularly in the US.

Recently there has been interest in low-earth orbiting (LEO) satellites. Here, a satellite placed in a 1000Km orbit has an orbital time of 1 hour. These satellites can be operated in a store-and-forward mode, picking up data at one part of the globe and physically transferring it to another. Because the data-rates and orbit radius are greatly reduced, small, low-cost satellites and ground stations are possible. However, such satellites have yet to demonstrate any commercial success.

1.4 Carrier To Noise Density Ratio

P_R / P_o is traditionally referred to as the C/N_o Carrier-to-Noise density ratio. The word "density" is used because the bandwidth of the signal is not taken into account as shown in figure 1.9 below.

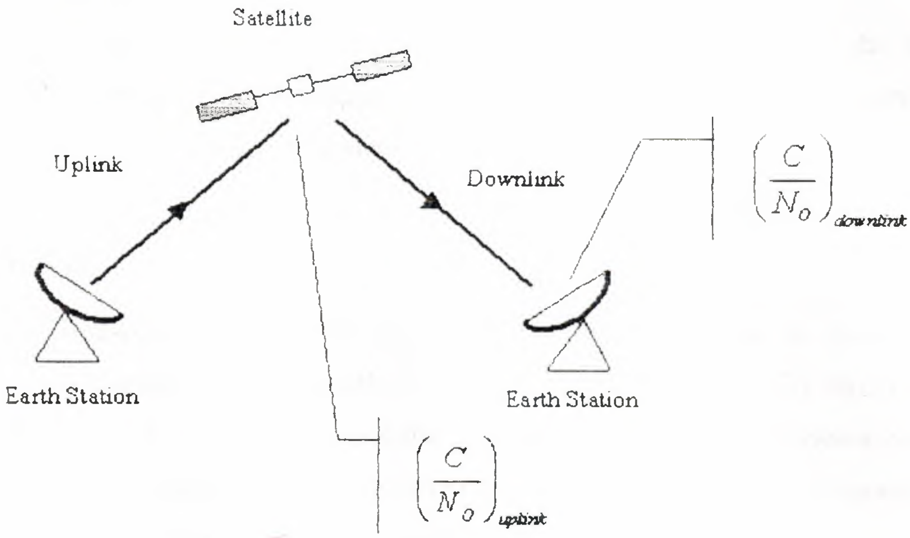


Figure 1.9: Carrier-to-Noise density ratio

Only if the received power is in the form of a digitally modulated signal, can we use $P_R = r_b E_b$. Thus, for most links budgets, the carrier-to-noise density ratio is calculated first. If the satellite communication system simply relays the signal from one Earth station to another, then the overall carrier to noise density ratio is given by

$$\left(\frac{C}{N_o}\right)_{overall} = \left[\left(\frac{C}{N_o}\right)^{-1}_{uplink} + \left(\frac{C}{N_o}\right)^{-1}_{downlink}\right]^{-1}$$

1.5 Channel Capacity Theorem

1.5.1 Fourier

Jean Baptist Fourier showed that the most complex time-varying analog signal could be decomposed into separate frequency components. each one being a simple sinusoid of a different frequency and phase. For example, consider the Fourier spectrum of a periodic signal. A periodic signal, in relation to computers, in information management and on communications networks, a name or label used as an alternative means of referring to someone or something. On networks, where they are commonly encountered, identify both individuals and groups of people with a common interest. Groups are particularly useful because a message addressed to the alias reaches each person in the group, simplifying the task of distributing information to multiple recipients.

1.5.2 Bandwidth

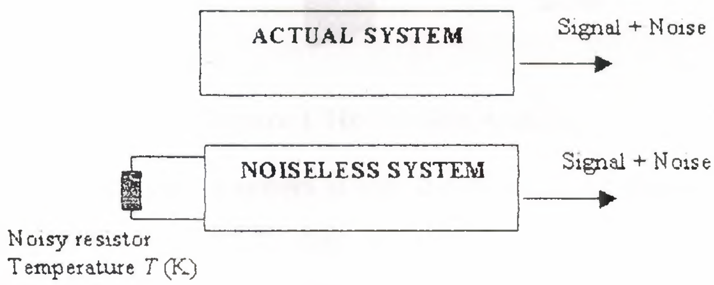
The bandwidth of a signal is a range of frequencies occupied by the signal's Fourier components within its frequency spectrum. This frequency range transmitted is typical chosen to be those components, which encompass most of the original signal energy.

1.5.3 Channel

The bandwidth of a channel is the range of frequencies that is passed by the channel. For example, the bandwidth of a telephone channel is typically the frequency range 300 to 3400 Hz. To determine the bandwidth of channel, a sinusoidal wave of frequency f and amplitude A is transmitted through the channel. The frequency f is varied and plotted versus the received signal amplitude.

1.5.4 Noise Temperature

The equivalent noise temperature T of a system is defined as the temperature at which a noisy resistor has to be maintained such that, by connecting the resistor to the input of a noiseless version of the system, it produces the same available noise power at the output of the system as that produced by all the source of noise in the actual system.



G_R/T ratio is typically provided for the satellite receiving system. The larger its value, the better the system.

1.6 The Anatomy of a Satellite

Satellites have only a few basic parts: a satellite housing, a power system, an antenna system, a command and control system, a station keeping system, and transponders.

1.6.1 Satellite Housing

The configuration of the satellite housing is determined by the system employed to stabilize the attitude of the satellite in its orbital slot. Three-axis-stabilized satellites use internal gyroscopes rotating at 4,000 to 6,000 revolutions per minute (RPM). The housing is rectangular with external features as shown below in figure 1.10.

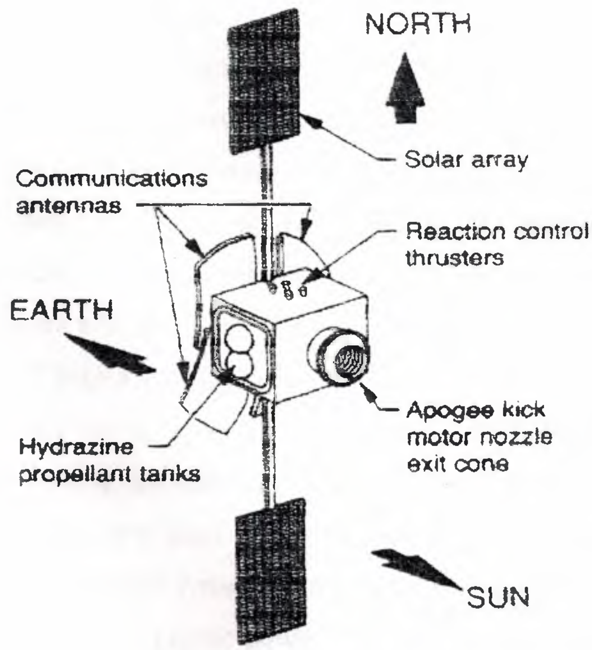


Figure 1.10: Satellite Anatomy

An alternative stabilization system is spin stabilization. As shown below in Figure 1.11, the housing of the INTELSAT spin-stabilized satellite is cylindrical and rotates around its axis at 60 to 70 RPM to provide a gyroscopic effect. To keep the antenna pointed in a fixed direction, it is connected to the body of the satellite by a rotating bearing. In spin-stabilized satellites, the solar cells are mounted on the cylindrical surface of the satellite. The materials used in the construction of satellite housings are typically very expensive. In newer satellites, lightweight and extremely durable epoxy-graphite composite materials are often used.

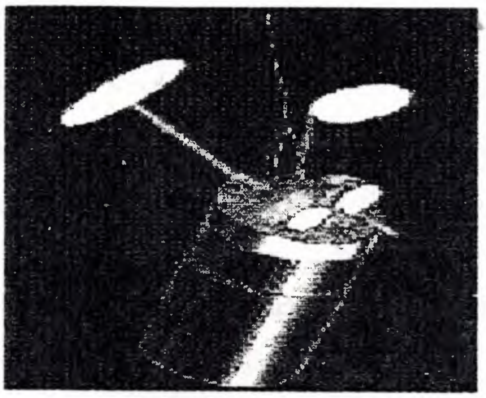


Figure 1.11: The Spin-Stabilized INTELSAT 6

1.6.2 Power System

Satellites must have a continuous source of electrical power--24 hours a day, 365 days a year. The two most common power sources are high performance batteries and solar cells. Solar cells are an excellent power source for satellites. They are lightweight, resilient, and over the years have been steadily improving their efficiency in converting solar energy into electricity. Currently the best gallium arsenide cells have a solar to electrical energy conversion efficiency of 15-20%. There is however, one large problem with using solar energy. Twice a year a satellite in geo-synchronous orbit will go into a series of eclipses where the sun is screened by the earth. If solar energy were the only source of power for the satellite, the satellite would not operate during these periods. To solve this problem, batteries are used as a supplemental on-board energy source. Initially, Nickel-Cadmium batteries were utilized, but more recently Nickel-Hydrogen batteries have proven to provide higher power, greater durability, and the important capability of being charged and discharged many times over the lifetime of a satellite mission.

1.6.3 Antenna System

A satellite's antennas have two basic missions. One is to receive and transmit the telecommunications signals to provide services to its users. The second is to provide Tracking, Telemetry, and Command (TT&C) functions to maintain the operation of the satellite in orbit. Of the two functions, TT&C must be considered the most vital. If telecommunications services are disrupted, users may experience a delay in services until the problem is repaired. However, if the TT&C function is disrupted, there is great danger that the satellite could be permanently lost--drifting out of control with no means of commanding it.

1.6.4 Command and Control System

This control system includes tracking, telemetry & control (TT&C) systems for monitoring all the vital operating parameters of the satellite, telemetry circuits for relaying this information to the earth station, a system for receiving and interpreting commands sent to the satellite, and a command system for controlling the operation of the satellite.

1.6.5 Station Keeping

Although the forces on a satellite in orbit are in balance, there are minor disturbing forces that would cause a satellite to drift out of its orbital slot if left uncompensated. For example, the gravitational effect of the sun and moon exert enough significant force on the satellite to disturb its orbit. As well, the South American land mass tends to pull satellites southward.

Station keeping is the maintenance of a satellite in its assigned orbital slot and in its proper orientation. The physical mechanism for station keeping is the controlled ejection of hydrazine gas from thruster nozzles which portrude from the satellite housing. When a satellite is first deployed, it may have several hundred pounds of compressed hydrazine stored in propellant tanks. Typically, the useful life of a satellite ends when the hydrazine supply is exhausted--usually after ten years.

1.6.6 Transponders

A transponder is an electronic component of a satellite that shifts the frequency of an uplink signal and amplifies it for retransmission to the earth in a downlink. Transponders have a typical output of 5 to 10 watts. Communications satellites typically have between 12 and 24 on-board transponders.

2. INTRODUCTION TO TRANSPONDERS

In the last few years the world has witnessed an enormous evolution in communications services - telephony, cellular, cable, microwave terrestrial, Internet and satellite. Successful design, planning, coordination, management, and financing of global communications networks requires a broad understanding of its segments, their costs, advantages and interfaces with other segments within the network. Satellite transponders, which are built and tested over many months under extremely rigorous conditions, are designed to function well beyond the normal lifetime of a spacecraft. That's why most geo-synchronous birds can continue to provide service for some customers even after they exhaust their fuel supply and can no longer maintain their stationary orbital position. Transponder complexity varies from the simple "bent pipe" approach to on-board processing (OBP) and on-board switching (OBS) transponders. Common elements include receivers, mixers, oscillators, channel amplifiers, and RF switches. OBP transponders may include additional elements of demodulators, de-multipliers, demodulators, and base band switches.

2.1 Purpose of Transponders

It is for the ATC controller to locate and identify transponder-equipped aircraft. Most ground stations have the capability to track both primary and secondary targets. The primary and secondary radar systems are synchronized together. The primary targets are aircraft (or flying saucers) that are not equipped with transponders. What we are referring to here is the reflection off the aircraft skin. Secondary targets are aircraft with working transponders. When the controller sees the Secondary target, they see the code selected in the transponder window along with Mode "C" altitude if present. Composite aircraft may not reflect the radar back so without a transponder system ATC may not see them at all. The controller also has the option to select only certain codes or aircraft with mode C only. Often in busy areas, the 1200 VFR code is blocked off the screen, so to get a clearer picture of the aircraft showing the codes the controller wants to see. This is why it's important to always have your eyes outside in VFR conditions.

2.2 Transponder Types

Due to manufacturing differences, not all transponders look the same. However, the transponders operate the same way. Different kinds of satellite are below.

2.2.1 Light Vehicles

A light vehicle transponder may be used only in light vehicles (cars, vans, limousines, pick-ups and sport utility vehicles) with a Registered Gross Vehicle Weight (RGVW) of 5,000 kilograms (five tones) and under. Transponders can be used in different vehicles of the same class. You may register a maximum of the three transponders on one personal account.

A light vehicle transponder cannot be used in a Heavy Vehicle. Use of the transponder in a heavy vehicle will result in the levy of a higher toll charge plus a flat toll charge of $25 per trip charged to your account. Remember, law for heavy vehicles to have a transponder in order to travel 407 ETR requires it. Transponders will not work if your car has a metallized windshield. Some of the vehicles that may have metallized windshields are: Cadillacs, Dodge Caravans, Chevrolet Luminas and Ventures, and Pontiac Trans Sport.

2.2.2 Heavy Vehicles

If you have a vehicle with a Registered Gross Vehicle Weight (RGVW) of over 5000 kilograms (five tones), you are required by law to have a heavy vehicle transponder. Examples of vehicles needing a heavy vehicle transponder are single unit trucks, tractors, school buses, transit buses, inter-city buses, and trucks or tractors with one or more trailers. If you choose to use 407 ETR without a transponder, you will be subject to a flat toll charge of $25 plus tolls per trip and you may be stopped by the Ontario Provincial Police and/or Ministry of Transportation Enforcement Officers, and fined.

2.2.3 Transparent Transponder

The basic function of the satellite transponder is to isolate individual carriers or groups of carriers and to boost their power level before they are retransmitted to the ground. The carrier frequencies are also altered as the carriers pass through the satellite.

Satellite transponders that process the carrier in this way are typically referred to as transparent transponders. Only the basic radio frequency characteristics of the carrier (amplitude and frequency) are altered by the satellite. The detailed carrier format, such as the modulation characteristics and the spectral shape, remains unchanged. Transmission via a transparent satellite transponder is often likened to a "bent pipe" because the satellite simply channels the information back to the ground. Some satellite designs go beyond simple transparent processing to manipulate the carrier's format. These are usually referred to as on-board processing systems. EUTELSAT's SKYPLEX technology is a practical example of this type of system. Although significantly more complex, such advanced architectures offer advantages over transparent alternatives, including improved transmission quality and the prospect of compact and inexpensive user terminals.

A typical on-board processing system will implement some or all of the functions that are performed by the ground-based transmitter and/or receiver in a transparent satellite system. These functions may include recovery of the original information on-board the satellite and processing of this information into a different carrier format for transmission to the ground. Any transponder that recreates the carrier in this way is usually referred to as a regenerative transponder.

2.3 III-Pulse Interrogation

All American and British aircraft and naval ships carried equipment during World War II. This equipment contain an emergency switch that, when turned on by a crew member of an aircraft in distress, immediately alerts the interrogating radar set and indicates the position of the aircraft. The ground station usually consists of three transmitting antennas the Primary target antenna, the Directional antenna and the omnidirectional antenna. The primary target antenna only shows aircraft without transponders if they have a reflection. The purpose of the Directional antenna is to interrogate the aircraft so it will send a reply back down to the ground station. This antenna sweeps around and the controller usually gets a 360-degree view. The directional antenna also tells the transponder to reply to Mode A and/or Mode C. Mode A is the code that you have selected on the front panel of the transponder. Mode C is the altitude-reporting portion (if equipped). Usually the ground station can transmit up to 110 miles and transmits on a frequency of 1030 megahertz. The information transmitted back down from the transponder is then massaged and shown on the controller's screen. By now you are probably wondering about that Omni-directional antenna. That's the most important one of all. The omni-directional signal is very weak compared to the directional antenna. This antenna puts out a signal called P2. The directional antenna puts out P1 and P3. If P2 becomes anywhere near as strong as P1 or P3 then the transponder will not reply. The reason for this is the side lobe of the directional beam and the ground station would somewhere else behind. As in figure 2.1.

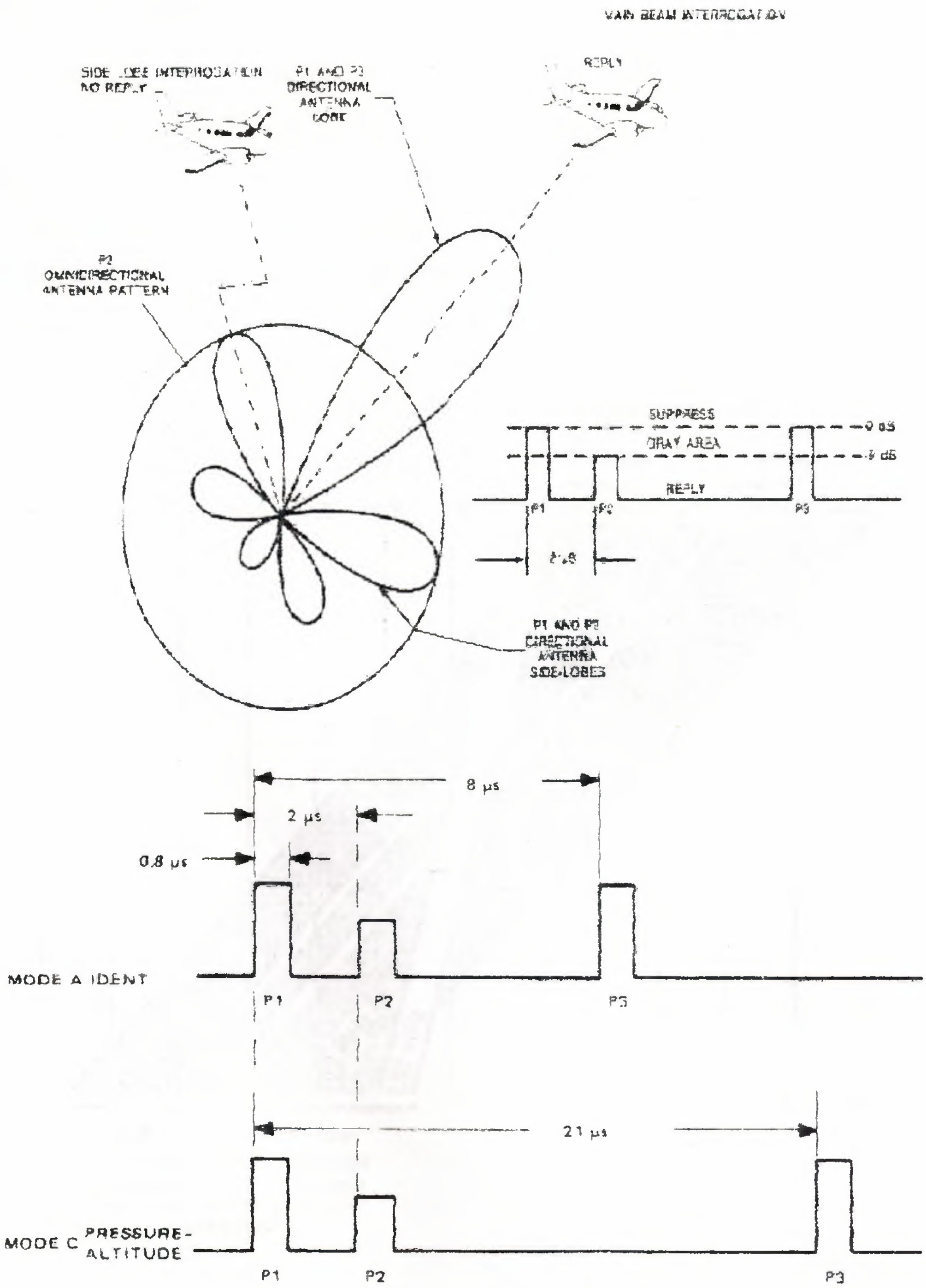


Figure 2.1: III-Pulse Interrogation Signal

2.4 Frequency Plans

To transmit signals by transponder, different kind of frequencies required. Some important properties of these frequencies are given below:

2.4.1 Frequency Chanalization

Figure 2.2 shown below shows a transponder frequency plan for the USA DSCS Phase II Satellite. The satellite employs two narrow-coverage (NC) antennas, which share the NC transmit power, and a single earth-coverage (EC) antenna. There are redundant TWT power amplifiers for both the NC output channel and the EC output channel I.

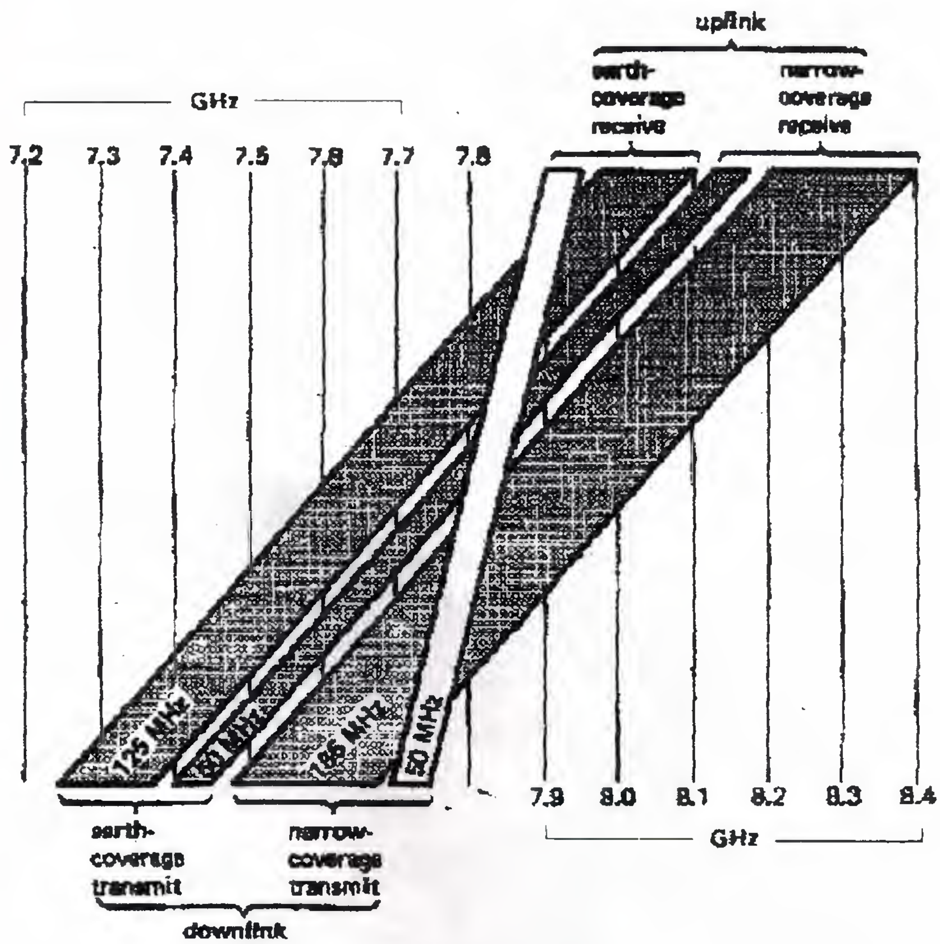


Figure 2.2: transponder frequency

In this transponder, uplink power from a user in the narrow-coverage beam (-2.5°) of the satellite can be transmitted either the earth-coverage or narrow-beam downlink antennas. The power is split to each of two narrow-beam antennas. Similarly, carriers in the earth-coverage uplink channel are directed to either downlink narrow-coverage or earth-coverage antenna, depending on the frequency of the uplink carriers. Thus an earth terminal situated in the beam width (=1000 nm diameter) of the NC antenna can transmit up to the satellite in either the NC or EC uplink bands and by proper frequency selection can transmit down in either NC or EC channels.

The earth-coverage transmit channels (7250 to 7450 MHz) for a 200-MHz band arc separated from the earth-coverage receive channels (7900-8100 MHz) by 450 MHz. Therefore, if there were not adequate transmit filtering in the TWT outputs, the seventh-order (4, 3) cross-product of two uplink carriers could fall as high as 7450 + 3(200) = 8050 MHz and into the earth-coverage receive channel. The third- and fifth-order cross products, however, cannot fall into a receive channel from the earth coverage transmit channel.

2.4.2 Frequency Reuse

Frequency reuse is the technique for transmission of two separate signals in the same frequency band by use of two separate types of antenna beams. Figure 2.3 shows an artist's conception of a satellite employing vertical and horizontal polarizations, and employing polarizes in front of the antennas.

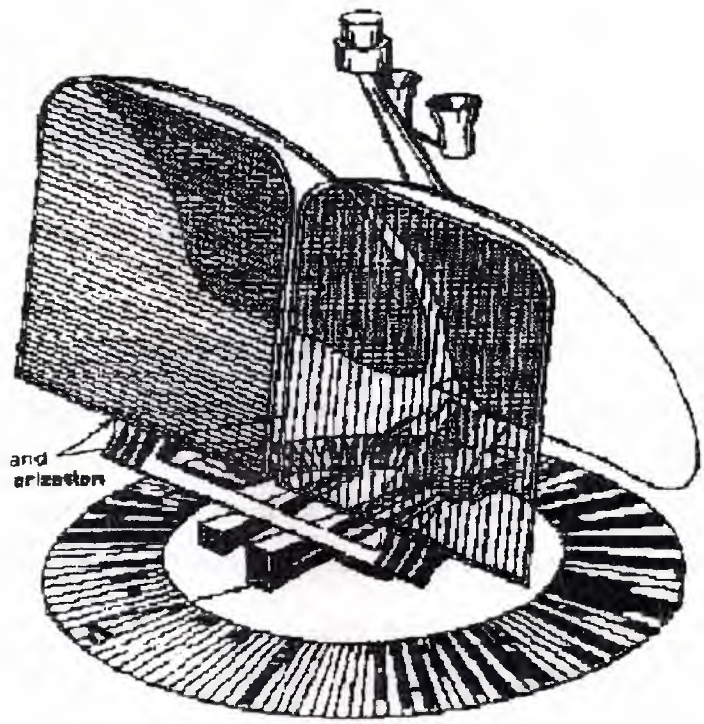
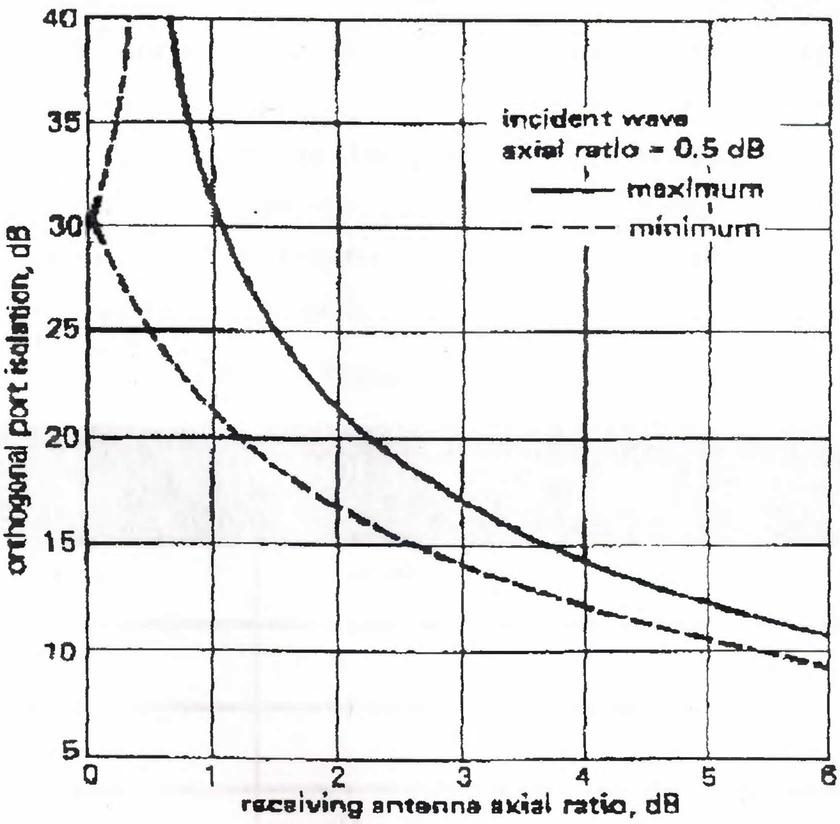


Figure 2.3: Artist's conception of a satellite

The technique of particular importance here is the use of two coincident antenna beams of orthogonal polarizations, that is, vertical and horizontal polarization or right- and left-hand circular polarization. Conception of a satellite employing frequency reuse through transmission of vertical and horizontal polarizations are shown below:

Graph 2.1 : polarization isolation characteristics.



2.5 Reception of Transponders

Satellite Transponders Are Good Listeners As They Receive, Process and Transmit Signals From Afar Picture yourself floating in space 22,300 miles from Earth. Your assignment is to detect incoming broadcast signals that arrive half a trillion times weaker than they started out. Then you must clean up the signals, amplify them by 100 billion times or so and retransmit them back to Earth. One more thing: You'll have to perform this task flawlessly, 24 hours a day, for at least 10 years with zero maintenance.

Not for satellite transponders, so named because they transmit and respond to signals automatically. Their signal-relaying function is the heart of a communications satellite, according to Andy Kopito, operation leader for Payload System Engineering at

Boeing Satellite Systems. A typical transponder consists of various components that perform four basic functions:

1. Amplify the incoming broadband signal and filter out noise
2. Separate the channels contained within the broadband signal
3. Amplify each channel
4. Recombine the channels into one broadband signal for retransmission

Almost all transponders currently in orbit relay signals without changing them. But that role is about to expand in new satellite systems offering advanced global mobile telecommunications services. The transponders on these birds will perform on-board signal processing and switching, redirecting signals among a large number of narrow spot beams. A typical geo-stationary satellite is equipped with transponders for one of the given below frequency bands.

Table: 2.1: Frequencies used by transponders.

FREQUENCIES (GHz)		
BAND	**UPLINK**	**DOWNLINK**
L	2	1
C	6	4
Ku	14	12
Ka	30	20
V	50	40

The spacecraft "sees" a wide spectrum of channels within each band from one or many sources on the ground. Its receivers initially amplify all channels together by about 60 decibels (dB), using special low-noise amplifiers and additional filters to remove signal noise. (Satellites designed to perform on-board processing would manipulate incoming signals at this point.) Multiplexes then separate the channels--a step called "Channelization"--and route each one to its own high-power amplifier. A second set of multiplexes recombines the amplified channels for broadcast as a single broadband signal back to Earth. To prevent the powerful downlink signal from overpowering the weak uplink signal, the satellite's transponder receivers perform an automatic frequency shift within their assigned operating band. Downlink frequencies are typically lower than uplink frequencies.

There are two types of high-power transponder amplifiers, and many geostationary satellites carry both. Solid-state power amplifiers (SSPAs) are all-electronic devices that operate on the same principle as a home stereo, albeit at vastly higher frequencies and power levels. Traveling wave tube amplifiers (TWTAs) use foot-long vacuum tubes to do their amplifying. SSPAs are compact, lightweight and relatively inexpensive. But as frequency and output power requirements rise, Kopito says, TWTAs are used due to their superior power efficiency. SSPAs are generally used in all L-band transponders, in moderately powered C-band transponders and in low-power Ku-band devices. TWTAs are usually specified for C-band systems over 30 watts, Ku-band systems over 20 watts and transponders operating in Ka-band or above. The breakpoint, Kopito notes, may be different for medium and low Earth satellites because their lower altitudes mean they can rebroadcast at relatively lower power levels.

Determining where to mount transponder components inside a satellite depends upon their function. Thus the high-power power amps go near the satellite's output antennas to maximize efficiency. To avoid the heat these big amps generate, the sensitive electronics of low-noise amplifiers and receivers are placed at some distance away in a special "low-temperature" zone.

Packaging also varies from one satellite design to another. In "spinner" satellites such as the Boeing 376, for example, the high-power amps have always been located near the outer surface of the bird for easier heat dissipation. There's more choice in body-stabilized spacecraft such as the company's popular Boeing 601, Boeing 601HP and new Boeing 702 series which use heat pipes to move heat to radiators.

Since repairing problems in a geostationary communications spacecraft is impossible in the usual sense, these satellites carry backups for critical components such as the broadband receivers that handle all incoming signals. They also carry devices that permit ground controllers to adjust the gain or amplification level for each channel. When the satellite performs as expected, redundant equipment is never used. But if needed, it literally can be "rewired" into a satellite's circuitry by commands from the Earth.

2.6 Processing Transponders

Onboard satellite processing can take a number of forms. Among these processing functions are: (1) active switching to distribute various uplink signals to the appropriate downlink amplifier and antenna: and (2) detection of the digital signals on the uplink and their regeneration for the downlink. An example of this kind of transponder is shown below in figure 2.4.

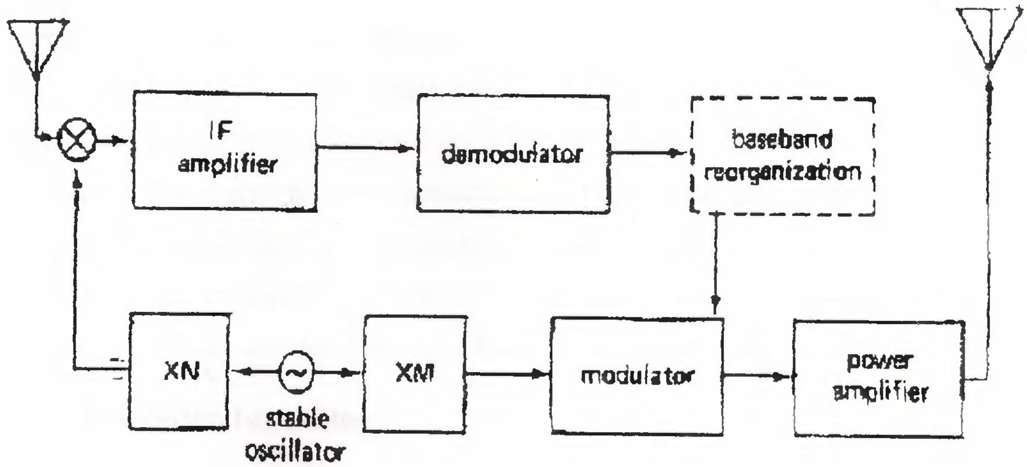


Figure 2.4: Modulation and Demodulating transponder

The use of switching includes a 'switchboard in the sky" concept, wherein different transponder input channels are switched by ground command to the appropriate downlink channel an alternative switching Concept employs a preprogrammed switching sequence to provide satellite-switched time-division-multiple-access (SS-TDMA). The use of active time-division switching in a satellite transponder offers improved bandwidth and power efficiency compared with, for example, an FDMA technique. Onboard demodulation of the uplink signals can improve the link performance.

For example where up- and downlink SNRs are equal, this regeneration provides almost 2.6-dB improvement in performance relative to a linear transponder; while the error rate at the output of the ground terminal remains the sane. Hence, if the SNR is the same at the regenerative satellite as at the receiving earth terminal, the error rates at the satellite and earth terminals are identical. Since these errors arc independent, the total error rate at the earth terminal output includes those errors generated by the satellite as well as those generated by earth terminal demodulation. Since these error rates are equal, the total error rate is double that of the satellite itself. This tandem error effect corresponds to <0.5-dB loss in signal power. On the other hand, a3-dB performance degradation occurs in a conventional linear transponder operating at the same power level when the earth terminal noise is added, and the error rate is thereby increased by approximately three orders of magnitude at low error rates.

Under many circumstances, however, the uplink SNR is relatively high, and there is little advantage to onboard regeneration. An exception occurs if either uplink interference is present or it is desired to multiplex and de-multiplex an uplink data channel in the satellite. The processing transponder constrains the type of signal that can be used to the particular modulation format built into the transponder. Thus the potential advantages of the regenerative transponder must be weighed against the constraints on signal modulation formats and the resulting lack of flexibility in changing modulation after the satellite is launched. In spite of these limitations, the potential for onboard processing, switching, and multiplexing of signals remains high.

2.7 Transponder Installment

The first thing to remember is the Mode C is always referenced to pressure altitude, which is 29.92" barometric pressure. The important thing to remember is that you should have your altimeter barrow-scale set at the pressure the controller has given you. Now you say, "if my altimeter is set at let's say 30.23" and Mode C is putting out at 29.92 there will be an error on the controllers screen! The controller's computer will take the Mod "C" output based on 29.92" and convert it to barometric pressure at your present position. Now the controller sees you at the altitude showing on your altimeter, we hope... You just learned something, huh? According to the FEDS, the encoder and altimeter must be within 125 feet of each other. If you get too much error (normally 300") ATC will have to stop squawking altitude. This is not a good thing. At that point you should visit your friendly avionics shop to get the altimeter and encoder married. I would explain how they are married, but marriage is not by expertise. The encoder is tied into the same static line as the altimeter, and is wired to the transponder. Some folks have an encoding altimeter, and these are great, but fairly expensive. The advantage is they take less space and are easier to install. It is basically altimeter and encoder in one case.

2.8 Multiple Accesses

One advantage of communications satellites over other transmission media is their ability to link all earth stations together, thereby providing point-to-multipoint communications. A satellite transponder can be accessed by many earth stations, and therefore it is necessary to have techniques for allocating transponder capacity to each of them. If the transponder capacity is 120 Mbps, this can handle about 3562 voice channels at 32 kbps, assuming the transponder efficiency is 95%. It is the unlikely that a single earth station would have this much traffic, there fore the transponders capacity must be wisely allocated to other earth station

Further more, to avoid the chaos, we want to our earth stations to gain access to the transponders capacity allocated to them in an orderly session This called multiple accesses The most commonly used multiple schemes are:

1. Frequency Division Multiple Access (FDMA)
2. Time Division Multiple Access (TDMA).

FDMA has been used since the inception of satellite communication Here each earth station in the community of earth station that shares the transponders capacity transmits one or more carriers to the satellite transponders at different center frequencies. Each carrier is assigned a frequency band in the transponder bandwidth, along with a small guard band to avoid interference between adjacent carriers. The satellite transponder receives all the carriers in its bandwidth, amplifies them, and retransmits back to earth. The earth station in the satellite antenna beam served by the transponder can select the carrier that contains the messages intended for it. The carrier modulation used in FDMA is FM or PSK. In TDMA the earth stations that share the satellite transmission use a carrier at the same center frequency for transmission on a time division basis Earth stations are allowed to transmit traffic bursts in a period time frame called the TDMA frame.

The transmit timing of the bursts is care fully synchronized so that all the bursts arriving at the satellite transponder are closely spaced in time but don't overlap. The satellite transponder receive one burst at a time, amplifies it re transmit it back to earth. Thus every earth station in the satellite beam served by the transponder can receive the entire burst stream and extract the bursts intended for it. The carrier modulation used in TDMA is always a digital modulation scheme. TDMA possesses many advantages over FDMA, especially in medium to have traffic networks, because there are number of efficient techniques such as demand assignments and digital speech interpolation that are inherently suitable for TDMA and can maximize the amount of terrestrial traffic that can be handle by a satellite transponder. For example, a 72- Mhz transponder can handle about 1781 satellite PCM voice channels or 356 2 32 - kbps adaptive differential PCM channels, with a digital speech interpolation technique it can handle about twice this number, 3562 terrestrial PCM voice channels or 712432 - kbps adaptive differential PCM voice channels. In many TDMA networks employing demand assignments the amount of terrestrial traffic handled by the transponder can be increase many time. Of course these efficient techniques depend on the terrestrial traffic distribution in the network and must be used in situation that are suited to characteristics of the technique. Although TDMA has many advantages, these don't mean that FDMA has no advantages over TDMA. Indeed, in networks with many links of load traffic, FDMA with demand assignments, as overwhelmingly preferred to TDMA because of the low cost of equipment.

2.9 Hamming Distance

The following analysis is under the assumption of a noiseless channel can be done by using hamming distance. The information binary digits 01011010 are encoded by the systematic rate 2/3-trellis code. The example below shown in figure 2.5 illustrates the case where the codeword, which correspond to the signal points, are decoded and used within the Viterbi decoder to decode the information sequence. Instead of decoding each codeword as it arrives, the Viterbi decoder utilizes the code structure embedded across several codeword by using cumulative metrics. Indeed, the Viterbi algorithm compares the received codeword sequence with all possible valid codeword sequences within the trellis, and selects the closest path. The use of code words is only a means to compare the sequence of encoder state transitions that are possible with the state transitions represented by the received codeword sequence.

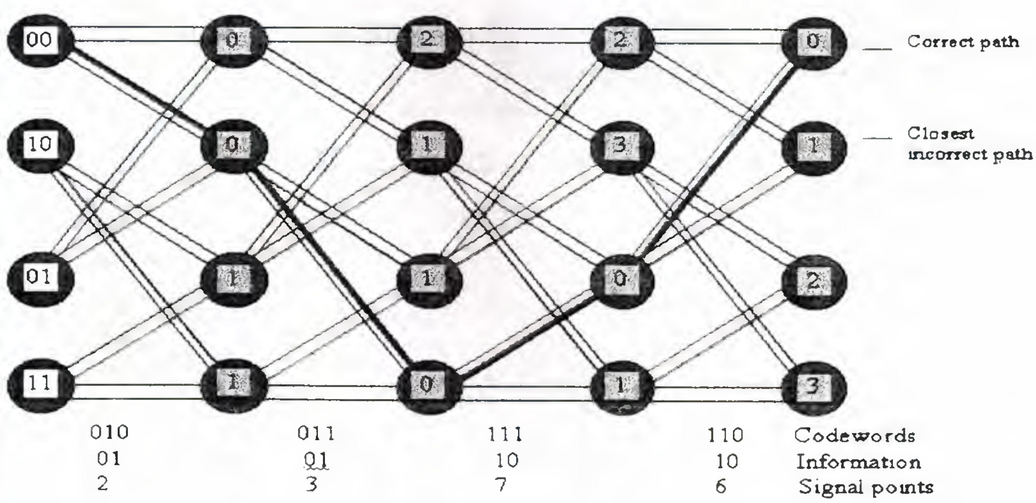


Figure 2.5: Example of hamming coding

Where

Surviving branch
Trace back path

By first demodulating a signal point to its corresponding codeword, vital soft-decision information has been lost that would otherwise have helped to improve the comparison of valid encoder state transitions with those represented by the received signal points.

2.10 Telemetry Tracking and Command (T T&C) Subsystem

The TT&C Subsystem contains Radio Frequency (RF) components, working in S-band, which provides the necessary functions to ensure Satellite access from the Ground Station for commanding and telemetry data transmission. The TT&C Subsystem includes:

1. Two S-band Transponders.
2. Two S-band antennas.
3. One Radio Frequency Distribution Unit (RFDU).

The Transponders are connected through the RFDU and RF coaxial cables to the two antennas that provide full spherical coverage with an overlap of at least ten degrees. The nominal operation scenario foresees that the Receiver sections of both Transponders are always switched on as shown in figure 2.6.

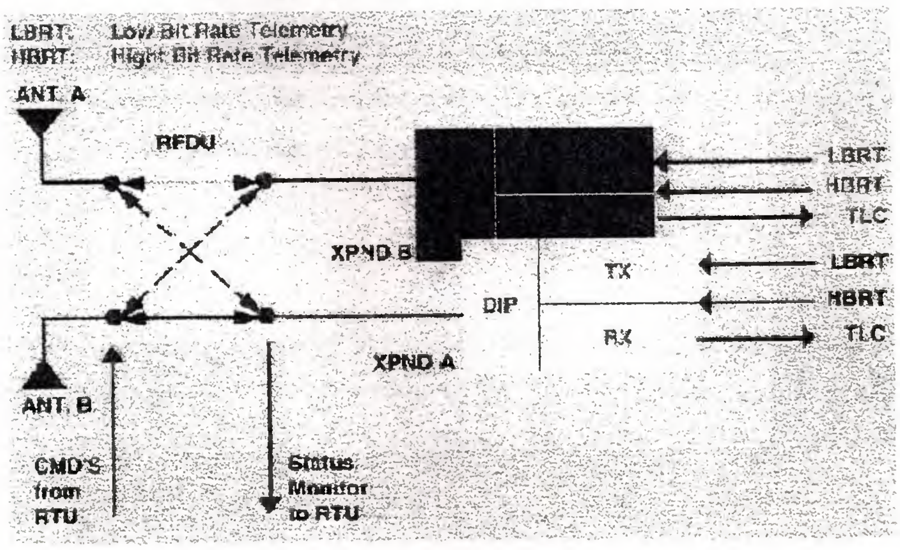


Figure 2.6: TT & C block Diagram.

Depending on the Satellite attitude during the Ground Station contact, only the Transmitter section of the Transponder connected to the ground-linked antenna is switched on. One Transponder failure can be recovered through a cross coupling in the RFDU to allow the connection of the still working Transponder with both the antennas.

2.11 Modulation Techniques

There are many kinds of modulation like frequency modulation, and amplitude modulation. Both terms apply to techniques for imposing a meaningful pattern of variations on an otherwise unvaried stream of energy during transmission, but they have also come to be applied to whole categories of broadcast radio. AM modulates the carrier radio wave by varying the amplitude (strength of the wave) in accordance with the variations of frequency and intensity of a sound signal, such as a musical note. Such modulation is vulnerable to electrical interference, and the sound quality is variable. FM works by varying the frequency of the carrier wave within a narrowly fixed range at a rate corresponding to the frequency of a sound signal. It is used within the VHF band, so that the terms "VHF" and "FM" have become synonymous for most radio listeners. FM reaches only to the horizon, so a transmitter's remit is local rather than national in scale. This geographical restriction has the advantage of reducing interference, and coverage is therefore more stable, day or night. The signal itself is inherently static-free, unlike that for AM, and a suitable receiving set can take advantage of its more generous frequency range and dynamic range to reproduce high-fidelity sound. But here we are using the prototype tagging system uses a frequency modulated 100 KHz carriers that is amplitude modulated onto the radar return signal to carry the ID back to the reader. This is decidedly sub optimal, though; all indications point to the use of a spread spectrum-coding scheme with CDMA for several reasons:

2.11.1 Reliability

It can be shown that spread spectrum systems can have a "processing gain"; this processing gain applies in the numerator of the radar equation along with increases in transmit power and antenna gain. This directly contributes to a better detection distance or improved reliability at a given distance.

2.11.2 Multiple Access

A satellite's power could now be concentrated on small regions of the Earth, making possible smaller-aperture (coverage area), lower-cost ground stations. An Intelsat 5 satellite can typically carry 12,000 voice circuits. The Intelsat 6 satellites, which entered service in 1989, can carry 24,000 circuits and feature dynamic on-board switching of telephone capacity among six beams, using a technique called SS-TDMA (satellite-switched time division multiple access). The present system can handle only one tag in the beam at a given time severe inter symbol interference between two visible tags at the same time renders the tagging system useless when presented with more than one tag at a time. A spread spectrum system could be designed using code division multiple access (CDMA) to decode many tags at the same time.

2.11.3 Security

The use of a spread spectrum system with a concealed synchronization method and spreading code renders the tag very difficult to pirate or hijack read. These benefits apply to both passive scattering tags and transponder tags; even more security is possible with a transponder tag as the transponder controller could be programmed to receive a challenge in one spreading code and transmit the response in another entirely different code.

2.12 Transponder Landing System

Airplanes are supposed to take people where they want to go. If where they want to go is in a small town and under the weather, airplanes can't get there. That situation is changing rapidly. There are at least two schemes around. GPS or Differential Global Positioning System (DGPS) is one idea that uses our celestial radio navigation system. Coupled with new and exotic gear in the cockpit it can make a near CAT I (or better) approach into remote locations. Precision instrument approaches into airports without the hectares of vacant ground around them, or airports without the economic benefit of thousands of flights each day.

This system is the Transponder Landing System, developed by Advanced Navigation and Positioning Corp. of Hood River, Ore. The concept is simple, the ground installation easy, and the potential applications are endless. The conventional Instrument Landing System has been around for a very long time. According to the book "Manual of Avionics", ILS was developed in 1946, and was finally deemed completely developed in 1973, when the solid-state systems were deployed.

We all know that the current ILS transmits a VHF localizer and UHF glide slope signal, modulated with 150 and 90 Hz audio tones. The modulation of these tones provides a measure of the deviation from the extended centerline of the runway, and a

3-degree sloped beam ending at about the runway threshold. By the very nature of the signals, the approach must be straight, and the landscape over which the beam passes must be electrically compatible with UHF and VHF Amplitude Modulation. By the time you invest in the electronics, real estate and illumination, you've spent well over a million dollars just for the installation. Then it must be maintained. As a result, the number of ILS-equipped runways is relatively small--about 1,000, compared to the more than 5,700 public airports in the United States. If you figure that each of those airports has two possible approaches, at least 91 percent of the runways do not have an ILS.

The Transponder Landing System is so very simple in design to be among the more elegant solutions in this world. Here is how the system works. Ground stations interrogate the standard ATCRBS Transponder. The replies are received by an antenna array that processes the signals and determines the position and altitude of the aircraft within the airport traffic area (actually out to about 22 nm). Altitude is independent of Mode C; the 3-D position is derived from the received signals much like a DF. Once the TLS has the position information, it transmits a signal to the aircraft that provides steering on the localizer and glide slope to touchdown. This can be curved, dog leg, step down--you name it. The ultimate goal is to steer the aircraft from where it is to the runway. Where a conventional ILS send out a fixed beam that the pilot aligns himself with, TLS actually adjusts the beam to bring in the airplane. In the cockpit, the instrument presentation is the same, just keep the needles centered.

When he contemplated leaving the world of military aviation, he had to see a future for the civil aviation industry. In his vision he saw 17,000 under-served airports, and 130,000 (by FAA account) aircraft equipped with conventional localizer and glide slope systems. His vision was cloudy when it came to Microwave Landing Systems, LAAS and WAAS DGPS systems. He could see the many popular resort destinations, like Sun Valley, Idaho, losing customers because of difficult access by air (with impossible access by land). The idea to put the existing systems together in a new way was first hatched in the early 90s, and in 1992, Advanced Navigation and Positioning Corp. was launched to make it happen. In these last six years the system has worked and been proven ever more robust in many situations. The next fully commissioned system won't be in the United States, however. Federal Express has a system installation at

Subic Bay, The Philippines, to serve the Asian hub. The terrain makes the approach ILS unfriendly; yet for FedEx, it absolutely, positively must be accessible.

The system can be delivered in a crate, set up and certified very easily. There are no site problems and the system is self-contained. Add a generator and the system can provide precision approach capability into any village, anywhere. Nepal? Stoltz has done that, in an A300 with a six-degree glide slope. One of the beauties of the TLS system, from Stoltz's view, is that the documentation already exists. The FAA and ICAO are familiar with what it takes on the aircraft side for an ILS approach. The TERPS (terminal instrument flight procedures) are commonly used.

There are few components in the TLS system. The most visible are four units mounted in a 50-meter radius alongside the runway. There is a base station unit, a Calibration/Built-in-Test (BIT) unit that monitors station accuracy and integrity, and two angles of arrival antennas. The localizer and glide slope angle of arrival AOA sensors are used to define the flight path from the transponder system as it nears the runway. A central processor in the base station computes the aircraft position in three dimensions, calculates where it should be in relation to the approach, and transmits corrections to the aircraft over the localizer and glide slope transmitter. Because the system can be programmed precisely for the location, the approach can be curves, segmented, dogleg, or whatever is necessary to avoid any obstacle along the approach path. These obstacles can be political, too. Some airports are considering TLS as a way to avoid noise sensitive areas on the approach. The glide slope is adjustable as well. Some airports, like Aspen, want a steep glide path. For helicopters anyway, even steeper approaches are possible. The basic TLS can provide guidance in an area that extends 45 degrees from the runway centerline. However, we think most airports would opt for some additional receivers that would extend the service area to 360 degrees around the runway, and 22 miles out.

The system is capable of tracking 25 aircraft (or even equipped ground vehicles as a way to prevent runway incursion accidents). One of the limitations of a single TLS system is that only one aircraft could be "on the beam" at a time, because the TLS generates a correction based on its position. However, the system isn't intended to replace the ILS at Denver International or DFW, with the constant parallel approaches. The TLS is a low traffic volume system.

2.13 Kinds of Transponders

2.13.1 Deep Space Transponder

The small deep space transponder combines the many separate functions that other spacecraft telecommunications systems perform into one unit. This unit has less than half the mass than would be required without this new technology. It contains several innovations that will help it meet the needs of many future missions.

The small deep space transponder has the ability to generate the beacon signals in Beacon Monitor Operations. Space projects that use the transponder will be saved the burden of designing their own telecommunications systems, and will be able to take advantage of the transponder's modern components and design techniques to save mass. The transponder has built into it the ability to use the new Ka-band radio frequency, which will improve the effect Telemetry Tracking, and Command (TT&C) Subsystem

2.13.2 Telephony Transponder

The Telephony Transponder is a program that is designed to indicate if a person is present by monitoring their telephone usage. At its simplest one can assume that if a telephone is currently in use then the owner of the telephone is present. On the obverse one can assume that the owner is not present if the telephone has not been used for a long period or if incoming calls to the telephone have not been answered. Further more complicated scenarios are possible. The Telephony Transponder is an application, written in Visual Basic, which runs on a PC under Windows. It communicates with a PABX (telephone exchange in a private network) using a Computer-Telephony Interface (CTI). This CTI is a special protocol, which has been developed to allow computer applications to get involved with the handling of telephone. calls by the PABX. The implementation developed for the VirtuOsi project uses a special CTI, which is specific to the iSDX and REALITIS range of PABXs manufactured by GPT Limited. This is not a TAPI link as the application is not associated with any one specific telephone, i.e. it is a 3rd party interface. The CTI link, which uses TCP/IP, allows the Telephony Transponder to monitor the activity of telephones on the PABX. The Telephony Transponder uses this monitor information to build up a picture of the usage of each telephone over time.

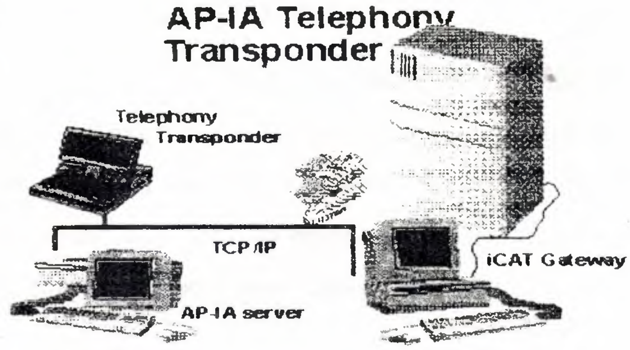


Figure 2.7: Telephony Transponder

The Telephony Transponder is also linked, via TCP/IP, to the Rich Finger server called AP-IA and being developed by BT. This pulls together information from the Telephony Transponder and other transponders (such as for screen savers, Mail system access, diary etc.) developed for VirtuOsi to provide a better picture of the user's availability.

The Telephony Transponder responds to availability requests from the server by providing an intelligent assessment of the user's availability based on their telephone usage. For security reasons the information that the Telephony Transponder provides is carefully restricted so that the Big Brother syndrome is not invoked. In practise the Telephony Transponder provides no more information than could be gleaned by someone within earshot of a target telephone. The power of the Telephony Transponder lies in that the enquirer may be remote from the target telephone.

The Telephony Transponder has been developed as part of the VirtuOsi project's research into how Virtual Reality could be used to support distributed business applications. The concept has been to provide a link from cyberspace to real space so that remote locations (potentially on the other side of the world) could be investigated from cyberspace. A typical example is visiting a remote office, which is modeled in cyberspace, to determine who is available to be consulted etc.

However the use of the Telephony Transponder is not limited to cyberspace and it is planned to be implemented by another VirtuOsi partner, BICC, as part of the VirtuOsi Factory pilot and accessed from specially developed PC console applications.

2.13.3 Transponders, TWTAs, and SSPAs

In a communication satellite serving the earth, the transponder transforms the received signals into forms appropriate for the transmission from space to earth. The transponder may be simply a repeater (a "bent pipe") that merely amplifies and frequency shifts the signals, or it may be much more complex, performing additional functions including signal detection, demodulation, de-multiplexing, re-modulation and message routing.

In this section, the technologies of the major transponder elements are presented, with major emphasis on the transmitters and amplifying devices, i.e., the traveling wave tube amplifiers (TWTAs) and the solid-state power amplifiers (SSPAs).

2.13.4 ID 100 Implant able Transponder

1. Designed especially for animal identification.
2. Biocompatible glass encapsulation.
3. Pre-sterilized, and ready-to-use.
4. Individually packaged in a disposable syringe.
5. Small size is suitable for use in even the smallest species.

This kind of transponder is shown in below:

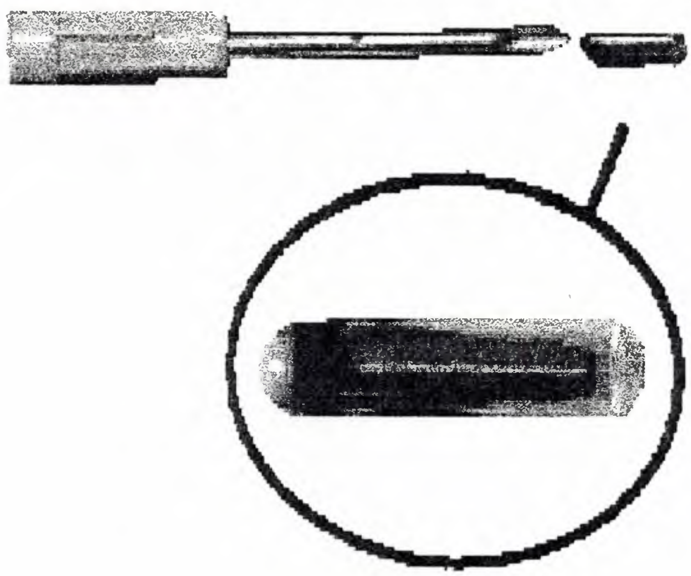


Figure 2.8: ID 100 Implant able Transponder

1. Endorsed by the Captive Breeding Specialist Group (C.B.S.G.) of the International Union for Conservation of Nature.
2. Used in over 300 zoos worldwide.

3. Used by over 80 government agencies in 20 countries.

4. Longest read range in any micro-transponder available today: enhances safety of shelter personnel and ensures transponder detection.

5. Only micro-transponder that can be read using a walk-by reader.

6. Typical read range:
180 mm (7 in.) w/ LID-500 reader
380 mm (14.9 in.) w/ LID-504 reader

1. Dimensions:
2.12 x 11.5 mm (0.08 x 0.45 in.)

3. FREQUENCY DIVISION MULTIPLEXING

Frequency division multiplexing (FDM) is the simultaneous transmission of multiple separate signals through a shared medium (such as a wire, optical fiber or light beam) by modulating, at the transmitter, the separate signals into separable frequency bands, and adding those results linearly either before transmission or within the medium. While thus combined, all the signals may be amplified. conducted. translated in frequency and routed toward a destination as a single signal, resulting in economies, which are the motivation for multiplexing. Apparatus at the receiver separates the multiplexed signals by means of frequency passing or rejecting filters, and demodulates the results individually, each in the manner appropriate for the modulation scheme used for that band or group.

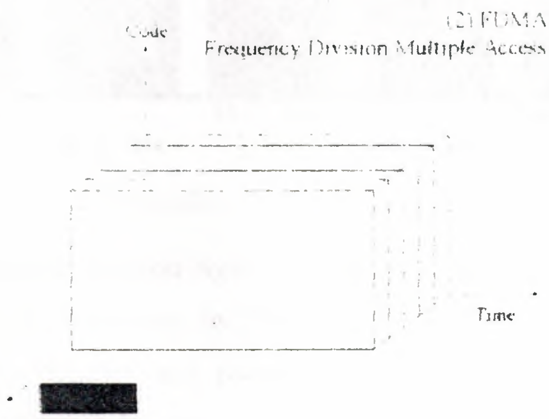
Bands are joined to form groups, and groups may then be joined into larger groups; this process may be considered recursively, but such technique is common only in large and sophisticated systems and is not a necessary part of FDM.

The FDMA class of signals includes many variations in the number and bandwidth of carriers transmitted by a given earth station. For example, we might transmit only one carrier per earth station, where the data to all receive terminals is multiplexed on that single carrier. Alternatively, each terminal might transmit separate carriers for each receive earth terminal being addressed. This latter approach has the advantage that it requires the receive earth terminal to demodulate only the data intended for it, but this technique may not have any power or efficiency advantage. Finally, one can provide a separate carrier for each voice channel. This single-channel per carrier (SCPC) system has the advantage that it can be used in a demand-assigned mode and can thereby improve the system efficiency. These SCPC carriers can also be voice- activated such that carrier power is turned on only during time intervals when the voice envelope exceeds a threshold level.

Neither the transmitters nor the receivers need be close to each other; ordinary radio, television, and cable service are examples of FDM. It was once the mainstay of the long distance telephone system. The more recently developed time division multiplexing in its several forms lends itself to the handling of digital data, but the low cost and high quality of available FDM equipment, especially that intended for television signals, make it a reasonable choice for many purposes.

3.1 Frequency Division Multiple Access

With FDMA the bandwidth of the channel is divided among the population of stations. For example, with six stations the frequency range of the channel is divided by six and each station gets its own private frequency. In this way there is no interference between users. Frequency division multiplexing is show below in figure 3.1.



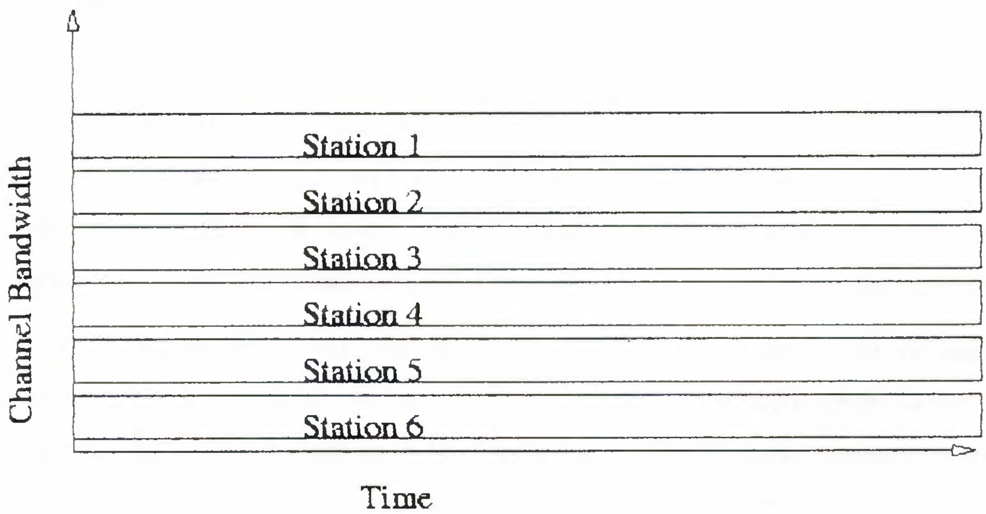


Figure 3.1: Frequency Division Multiple Access

In the receiving station the composite signal is available at the output of the receiver demodulator, which is then fed to band pass filters that are tuned to the center frequencies of the sub carrier oscillators. The outputs from the filters are the demodulated and the original transducer signals are recovered. An other kind of frequency division multiplexing is show below in figure 3.2.

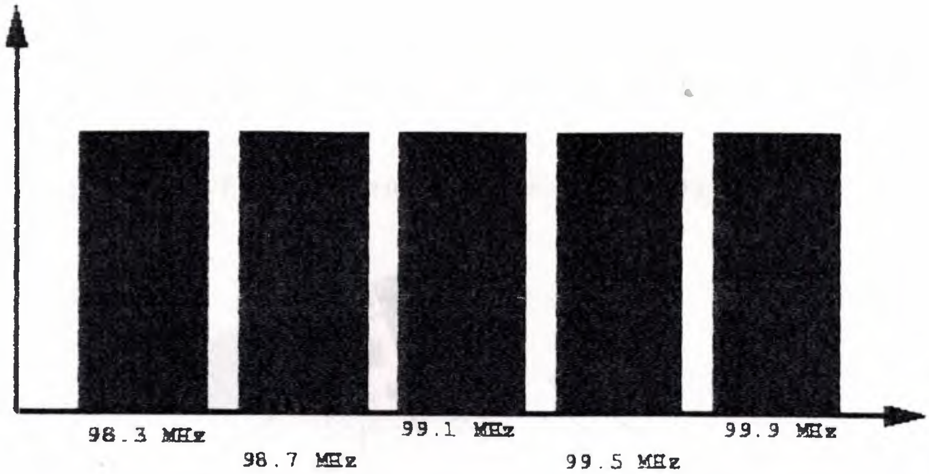


Figure 3.2: Frequency Division Multiple Access (FDMA).

Here we address the simplest form of multiple accesses wherein each carrier is transmitted at a different frequency. In FDMA, each signal is assigned a separate non overlapping frequency channel, and power amplifier inter modulation products are either accepted or minimized by appropriate frequency selection and/or reduction of Input power levels to permit quasi-linear operation.

Attention is focused on the satellite transponder effects since this power is more critical and costly than earth terminal power. Typically, one might reduce the satellite average output power by 50 percent or more to reduce IM products to an acceptable level with a high density of input signals. Oscillators with good long-term stabilization are employed to keep the signals properly centered in non-overlapping frequency bands.

The simplest and most widely used multiple access technique of satellite communications is frequency division multiple access, where each earth station in a satellite network transmits one or more carriers at, different center frequencies to the satellite transponder. Each carrier is assigned a frequency band (Be) with a small guard band (BG) to avoid overlapping between adjacent carriers.

The satellite transponder receives all the carriers in its bandwidth, amplifies them, and retransmits them back to earth. A frequency division multiple access system is shown schematically in figure shown below. In this type of system each carrier can employ either analog modulation, such as frequency modulation, or digital modulation, such as phase-shift keying. A major problem in the operation of FDMA satellite systems is the presence of inter-modulation products in the carrier bandwidth generated by the amplification of multiple carriers by a common TWTA in the satellite transponder that exhibits both amplitude non linearity and phase non linearity. As the number of carriers increases, it becomes necessary to operate the TWTA close to saturation in order to supply the required power per carrier to reduce the effect of downlink thermal noise. Frequency distribution is show below in figure 3.3.

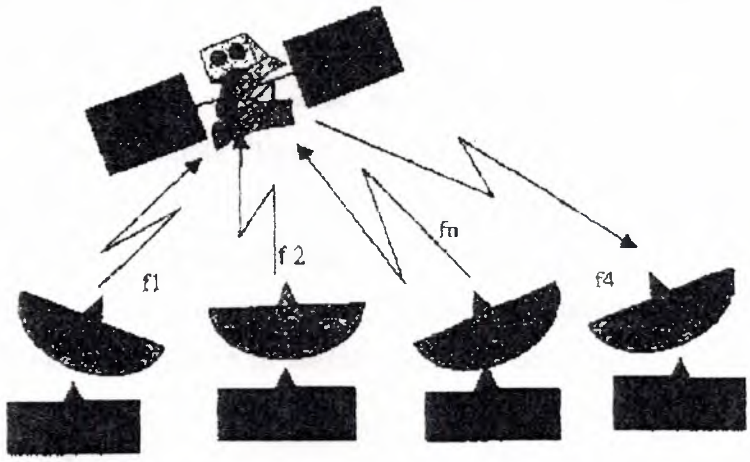


Figure 3.3: Frequency distribution.

But near saturation the input/output amplitude transfer characteristic of the TWTA is highly nonlinear, and consequently the level of inter modulation products is increased and affects the overall performance.

Inter-modulation noise distributed over the entire frequency band. This inter-modulation noise must be included in assessing FDMA performance. In order to do this, however, it is first necessary to derive a somewhat rigorous no linearity model that will analytically account for the inter-modulation terms.

3.2 FDMA Channelization

In wave motion of all kinds, the frequency of the wave is usually given in terms of the number of wave crests that pass a given point in a second. The velocity of the wave and its frequency and wavelength are interrelated. The wavelength (the distance between successive wave crests) is inversely proportional to frequency and directly proportional to velocity. In mathematical terms, this relationship is expressed by the equation *V* = ë f. where *V* is velocity, *f* is frequency, and ë (the Greek letter *lambda*) is wavelength. From this equation any one of the three quantities can be found if the other two are known.

We have found that when dealing with an FDMA system using nonlinear satellite amplifiers, the available satellite power in the downlink must be divided among all carriers. Furthermore, strong carriers tend to suppress weak carriers in the downlink. This means that, when a mixture of both strong and weak carriers are to use the satellite simultaneously, we must ensure that the weaker carriers can maintain a communication link, especially if the mixture is to be transmitted to a relatively small (small g/T) receiving station. One way in which weak carrier suppression can be reduced in FDMA formats is by the use of satellite Channelization. In Channelization, the strong and weak carriers are assigned frequencies so that they can be received in the satellite in separate RF bandwidths. That is, The total available satellite RF bandwidth (BRF) is divided into smaller bandwidths, and the uplink carriers are assigned frequencies so as to he grouped in a bandwidth with other carriers of the (approximate) same satellite power level.

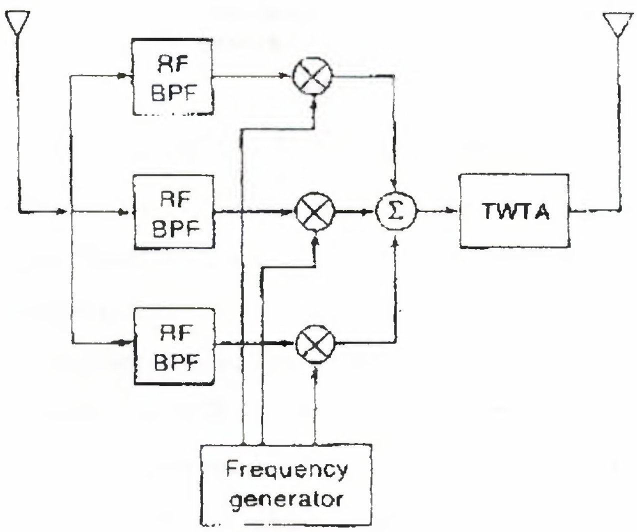


Figure 3.4: Single TWTA

These individual RF bandwidths are called satellite channels, and they can be used in two basic ways. One is to permit each channel to have a separate RF filter and amplifier, but to use only a single power amplifier. The outputs of all channel amplifiers are summed prior to limiting and power amplification. The advantage of the Channelization is that the amplifier gains in each channel can be individually adjusted so that all carriers will have roughly the same power levels when they appear at the amplifier input.

This prevents suppression effects due to strong uplink carriers, although the total number of carriers and the total amount of noise remains the same. In essence, uplink power control is obtained at the satellite instead of at the earth stations.

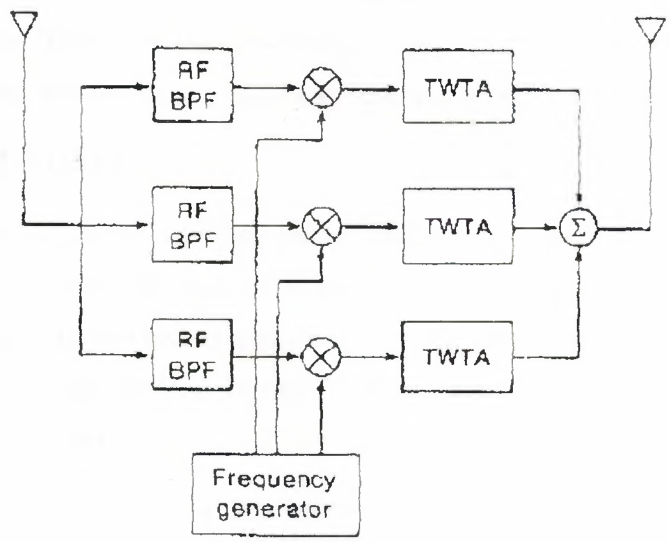


Figure 3.5: Multiple transponders

The second Channelization method is to use separate power amplifiers for each channel (as shown in figure b). Each satellite channel then becomes an independent transponder. Only carriers of the same power are used in the same channel. The power of each amplifier is therefore divided only among the carriers in its own bandwidth. The uplink noise per channel is reduced because of the smaller bandwidths, thus leading to improved CNR for the downlink. In addition, the inter-modulation and power suppression effects are reduced since there are fewer carriers in each transponder. The limit, of course, is when each uplink carrier is assigned its own transponder channel, which is the so-called SCPC (single channel per carrier) format and all nonlinear effects are removed. The advantages of Channelization are achieved, of course, at the expense of a more complex satellite, since the weight of not only the additional power amplifiers and filters must be included but also that of the supporting auxiliary primary power. The advantages in performance of the increased number of independent transponders must be carefully weighed against the additional satellite cost.

The use of increasing numbers of satellite transponders is an obvious trend in modern satellite design. Above figure shows the processing block diagram for the 12-transponder Intelsat satellite. The uplink and downlink RF bandwidth is divided, as shown in above figure b. Each individual transponder has a 36-MHz bandwidth, with each channel center frequency separated by 40 MHz. The 12 transponders therefore utilize the entire 500-MHz RF bandwidth. Satellites may employ additional channels by making use of antenna beam separation or antenna polarization separation in the uplink and the downlink. Recall that this allows frequency reuse, in which two separate carriers as the same uplink and downlink frequencies can use the RF bandwidth simultaneously.

3.3 FDM-FM-FDMA

Since the inception of satellites analog modulation, such as frequency modulation, has been used for carrier modulation in satellite communications using FDMA; it will probably be employed in existing equipment for years to come despite advances in the development of digital satellite systems. There are two main FDMA techniques in operation today as in figure 3.6.

Multi channel -per-carrier transmission, where the transmitting earth station frequency division-multiplexes several single sideband suppressed carrier telephone channels into one carrier base band assembly, which frequency-modulates a RF carrier and is transmitted to a FDMA satellite transponder. This type of operation is referred to as FDM-FM-FDMA. Single-channel-per-carrier transmission, where each telephone channels independently modulates a separate RF carrier and is transmitted to a FDMA satellite transponder. The modulation can be analog, such as FM, or digital, such as PSK.

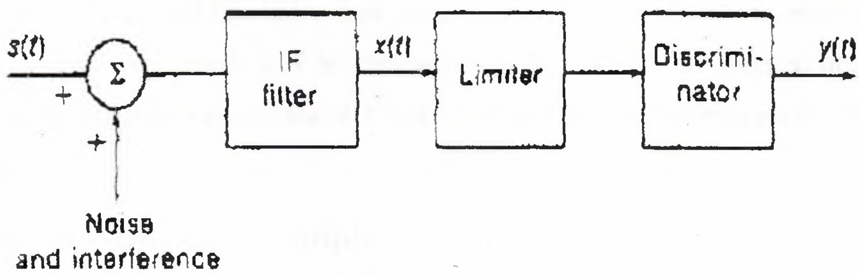


Figure 3.6: FDMA block Diagram

3.4 Single Channel Per Carrier

Unlike FDM-FM-FDMA systems, which serve large-capacity links, single-channel-per-carrier systems are more suitable for applications that require only a few channels per link. In these systems each telephone channel independently modulates a separate RF carrier and is transmitted to the satellite transponder on a FDMA basis. A 36-MHz transponder can carry as many as 800 voice channels or more. If the carrier modulation is digital, the performance is measured in terms of the average probability of bit error.

For analog carrier modulation, FM is employed.

1. FM-SCPC systems are the most commonly used systems because of their attractiveness in terms of cost and simplicity.
2. The design of a FM-SCPC link can be expressed in terms of the signal-to-noise ratio at the FM demodulator output, as in FDM-FM-FDMA.

3.5 FM-FDMA Television

Television broadcasting via satellite in the United States is among the most highly developed in the world. TV programming is distributed on the fixed satellite service portion of the C and Ku bands. In 1983 the Federal Communications Commission approved a frequency band for domestic direct broadcast satellite services (DBS) to provide direct-to-home television: an uplink frequency of 173 to 17.8 GHz and a downlink frequency of 12.2 to 12.7 GHz.

The DBS downlink portion of the Ku band is adjacent to the 11.7-to 12.2-GHz downlink frequency of the FSS portion of the Ku band. High-power direct broadcast satellites have many characteristics similar to those of communications satellites except that the DBS downlink radiated power is about 10 dB more per transponder.The powerful television signal lets individual users receive programs with antennas as small as 0.7 m in diameter, which can be mounted on the roof of an average house. The nominal carrier-to-noise ratio is about 14 to 15 dB when used with an earth station 0 T of 10 dB/K.

3.6 Frequency-Division Multiplex Telemetry System

Telemetry, in engineering, the use of electrical or electronic equipment for detecting, collecting, and processing physical data of one form or another at a given site, and then relaying this data to a receiving station at another site where the data can be recorded and analysed. One obvious use of telemetry, for example, is in the measuring, relaying, and recording of physical conditions encountered or produced by high-speed aircraft, rockets, and spacecraft. Such data might include air temperatures, wind speeds, or radiation intensities in outer space.

The matter of distance in telemetry is relative, however, because such systems may also be employed for obtaining data from sites that are near to the receiving instruments but that are difficult, impossible, or dangerous for human observers to encounter. For example, biological sensors of various kinds may be used within the human body to transmit information on medical conditions to detectors placed outside the body. Other examples include the use of telemetry for running tests of engines, for detecting flaws or changing conditions in industrial systems, or for obtaining data from dangerously radioactive sites. Meteorologists make use of a wide range of telemetric devices to obtain information from the upper atmosphere for use in making their weather forecasts. Such meteorological uses were, in fact, the first to which the techniques of radio telemetry were applied.

In any telemetric system, the equipment used must be able to make a measurement of a physical quantity, produce a signal that can be modified in some way to carry the measured data, and relay this encoded signal over some form of transmission link. The receiving equipment must then be able to decode the signal and to display it in some format for analysis and, probably, for recording. Usually more than one signal must be sent over the transmission link at any one time, in which case some form of multiplexing must be used. This can be done by employing different frequency bands for the measurement of different quantities or by splitting up the signal into discrete time intervals to which the quantities to be measured are assigned. The coding techniques used are commonly digital; the use of pulse-code modulation, by which continuous waves are transformed into a binary-code signal, has been enhanced in recent decades by the advances made in the digital computer field and in microelectronics.

The basic operation of a frequency-division multiplex telemetry system is illustrated in the figure below. The measurement signals from transducers modulate "sub carrier" oscillators tuned to different frequencies. The output voltages from the sub carrier oscillators are then summed linearly. The composite signal is used to modulate the downlink transmitter. All types of modulation can be used for both the sub carrier oscillators and the prime carrier. The transmission system for frequency division multiplex systems is designated by first giving the modulation for the sub carriers and then the prime carrier. Thus FM/AM would indicate a frequency-division multiplex system in which the sub carriers are frequency modulated and the prime carrier is amplitude modulated by the composite sub carrier signal.

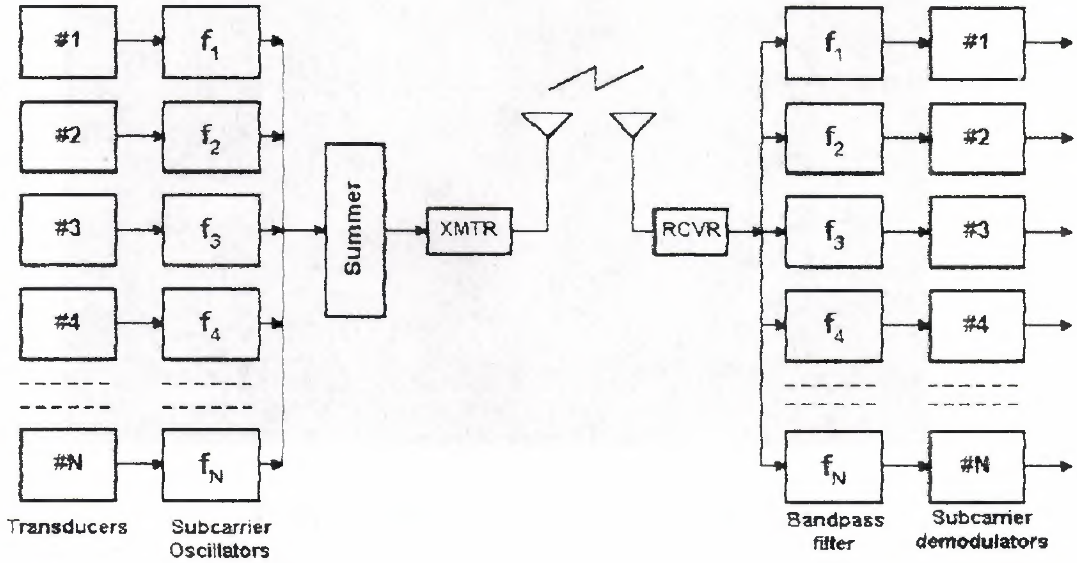


Figure 3.7: Telemetry system

The most commonly used frequency-division multiplex system is FM/FM. Standards were established in the U.S. for FM/FM systems shortly after World War II and they later became known as the Inter-Range Instrumentation Group (IRIG) standards. The FM/FM standard established the center frequency for sub carriers and how much bandwidth each sub carrier can occupy. The table below shows the IRIG FM/FM sub carrier channel assignments.

The most noteworthy variants frequency-division multiplex systems used in addition to FM/FM are FM/PM and SS/FM (for Single-Sideband/FM). An FM/PM system was used in the early days of the U.S. space program under the name of Micro lock, because phase-locked receivers were used to acquire and detect the main carrier. However, the amount of information transmitted in these early systems was very limited.

By using single-sideband sub carrier signals much more data could be compressed in a narrow bandwidth and the SS/FM systems were used in early Saturn I flights. The figure below shows about seven seconds of FM/FM telemetry from an Atlas rocket launched from Cape Canaveral in the early 60's.

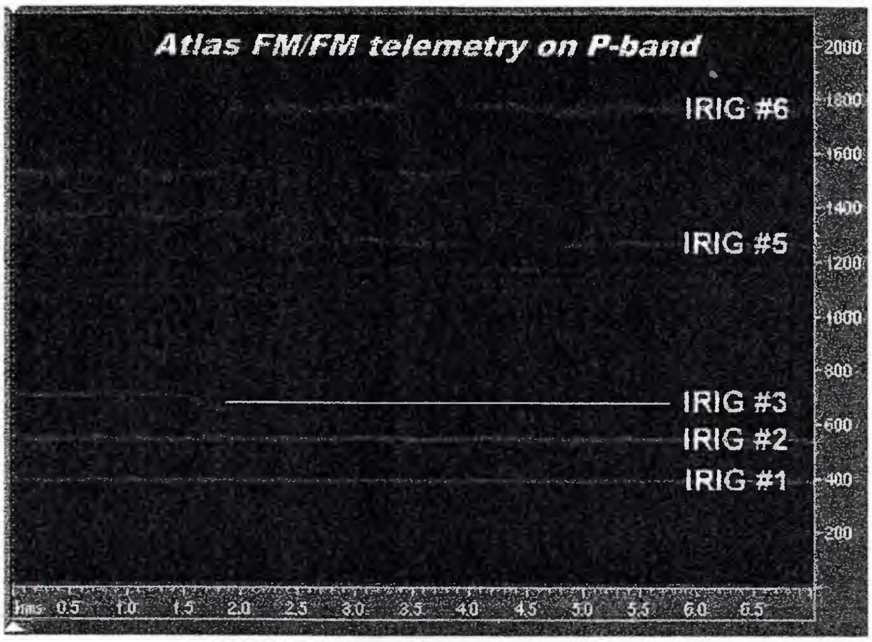


Figure 3.8: Seven seconds of FM/FM telemetry

The carrier frequency was in the P-band region, i.e. 215-260 MHz. The figure shows five sub carriers and their behavior at the time of booster engine separation. We can easily spot IRIG sub carriers 1, 2, 3, 5 and 6. It seems that IRIG 3 disappears at 1.9 seconds into the recording. By clicking on the spectrogram you can hear a sound file with these signals.

Normally, the outputs from the sub carrier demodulators in the receiving station were applied to banks of meters or to multi-channel strip-chart recorders. These recorders were either of the type with ink pens writing on moving paper, ultra-violet light beams drawing traces on UV-sensitive paper or so-called Sanborn recorders which used heat pens (hot wires which made black lines on special paper). I have myself been crawling on the floor at the Swedish rocket base range analyzing strip-chart recordings from a sounding rocket as they rolled out of the recorders in real time as in figure 3.9.

In the early days of telemetry Analogue Time-Division Multiplex systems were used in conjunction with frequency division multiplex systems. A very common type of time-division multiplex was the Pulse-amplitude modulation (PAM) system. The output of the commutator in such a system is a series of pulses, the amplitudes of which correspond to the sampled values of the input channels from the transducers. At the receiving station the process is reversed. The demodulator output from the receiver is passed through a de-commutator that produces outputs corresponding to the sampled measurement.

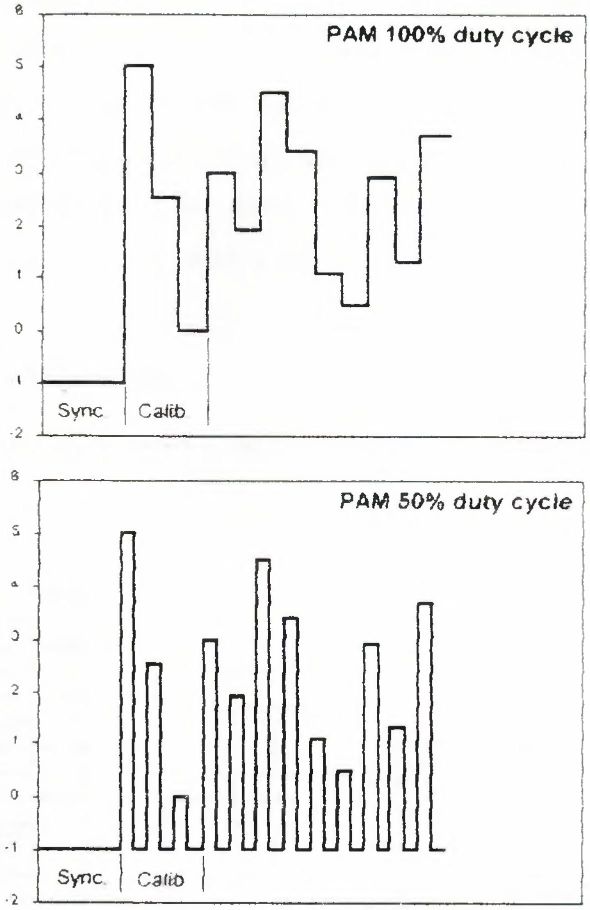


Figure 3.9: Pulse-amplitude waveform

The pulse-amplitude waveform may take several forms as can be seen below. The principle difference lies in the duty cycle of the pulse. In the figure 3.9 on the right the top diagram shows a 100% duty cycle system while the lower diagram shows a 50% duty cycle system signals.

The length of time necessary to sample all channels is called the "frame time". In order to identify the channel corresponding to a sample at the receiving station, it is necessary to provide frame synchronization. Several different methods can be used to designate the beginning of a frame. The method illustrated on the right consists of forcing several consecutive channels to a level below the minimum allowable data value. Since drifts and non-linearities cause errors, it is also common practice to transmit calibration pulses.

In addition to the primary time- and frequency-division multiplex techniques described here, there are cases in which these techniques are combined. One of the most common combinations has been that of PAM and FM/FM to form PAM/FM/FM. In this case a PAM time-division multiplex signal is used to modulate an FM/FM sub carrier. Several other sub carriers may also be modulated with separate PAM signals. Usually the higher frequency sub carriers are used for PAM signals and the lower frequency sub carriers are used for direct measurements. As an example, the PAM sampling rate for IRIG channel 5, with a sub carrier center frequency at 1300 Hz is 10 samples per second.

3.6.1 Example of PAM/FM/AM

The picture 3.10 below shows a piece of the telemetry transmission from Explorer-7.

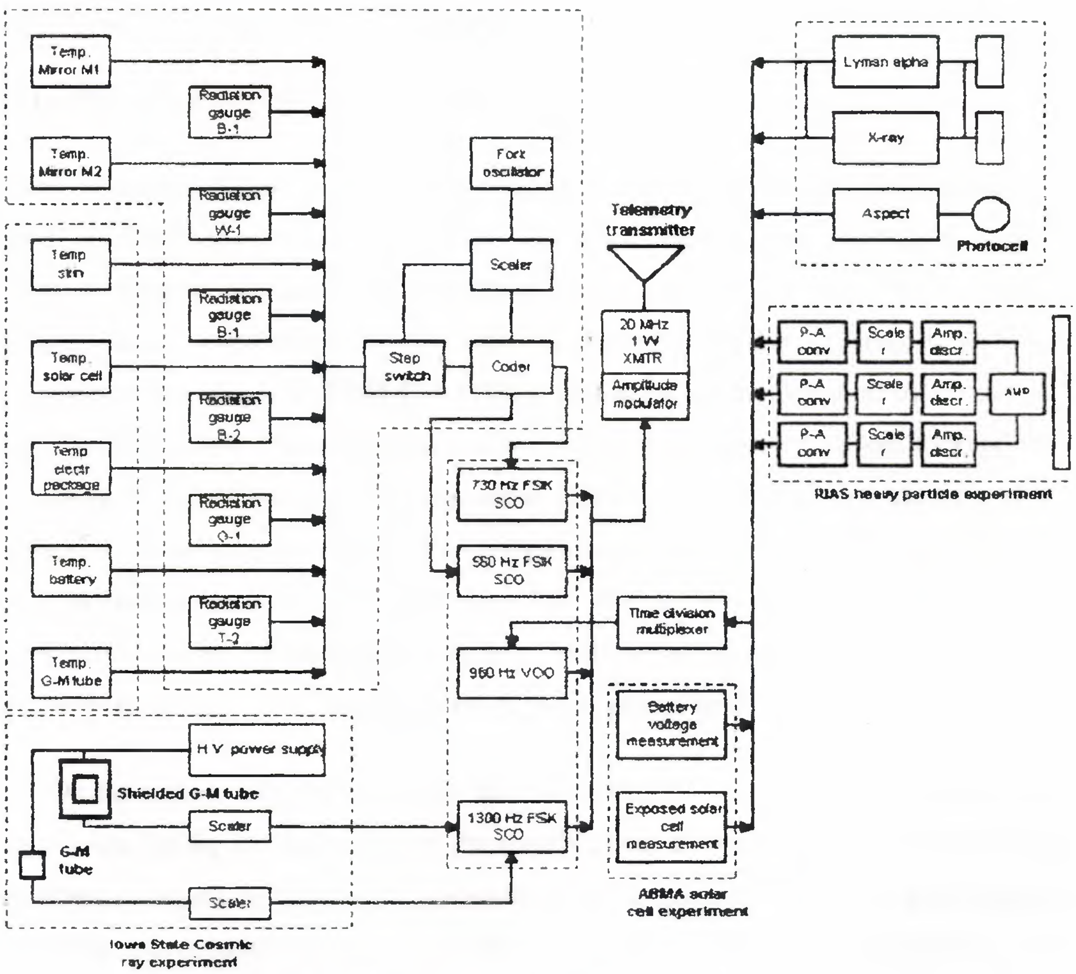


Figure 3.11: Example of telemetry system

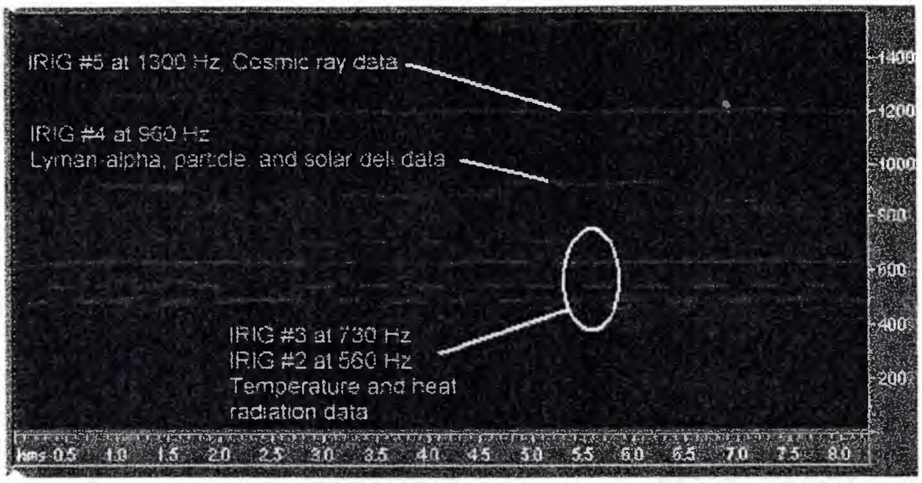


Figure 3.11: Telemetry transmission

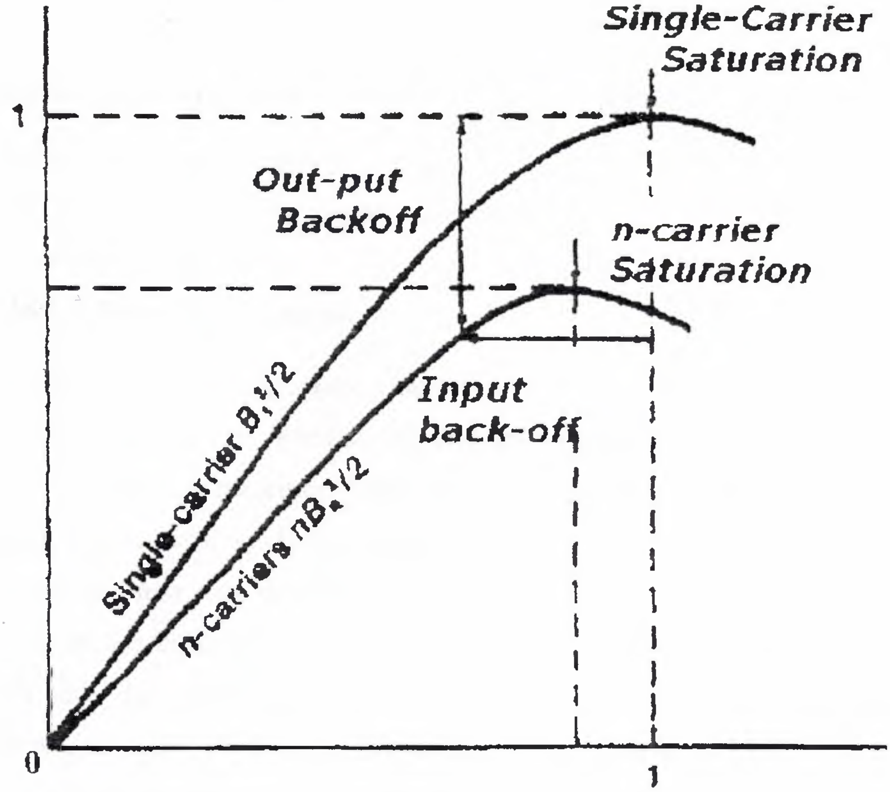
In real-life applications many sensors were multiplexed on each sub carrier. Explorer-7is a good example of this system. This spacecraft was also called S-46 and it used a PAM/FM/AM system on 20 MHz and PAM/FM/PM system on 108 MHz.

3.7 FDM-FM-FDMA Vs SSB-AM-FDMA

System of communication using electromagnetic waves propagated through space. Waves are used in wireless telegraphy, telephone transmission, television, radar, navigation systems, and space communication They are also used in radio broadcasting; the term "radio" is therefore most popularly applied to sound broadcasting in general. The transponder capacity in FDM-FM-FDMA operations can be improved by the use of syllabic compounders. The traditional use of syllabic compounders has been to improve the quality of signal transmission over poor channels. A compounded consists of a compressor at the transmit side of the satellite channel and an expander at the receive side. The compressor is a variable-gain amplifier that gives more gain to weak signals than to strong signals. This results in an improved overall signal-to noise ratio because the low-level speech signals are increased in power above the channel noise.

On the receive side, the expander restores the signals level by attenuating the low-level speech signals. During pauses in the speech signal, the expander, and hence giving further improvement in the overall subjective signal-to-noise ratio reduce channel noise. A 36-MHz transponder can accommodate a single FDM-FM-FDMA carrier of 1100 uncompounded channels. On compounding the channels. The capacity is increased to about 2100 channels. With over deviation beyond its allocated bandwidth (with no loss in the quality of the channels), such a transponder can carry about 2900 channels.

Graph 3.1: FDM-FM-FDMA Vs SSB-AM-FDMA



Recent use of solid-state power amplifiers with sufficiently linear characteristics to replace nonlinear TWTAs allows the use of compounded single-sideband-amplitude modulation-frequency division multiple access (SSB-AM-FDMA) to achieve 6000 channels per transponder of 36-MHz bandwidth for a single carrier.

Besides the high capacity, SSB-AM-FDMA offers another major advantage over FDM-FM-FDMA from a multiple access point of view. The capacity of a satellite transponder using SSB-AM-FDMA is not decreased by multiple accesses. Unlike FDM-FM-FDMA. Also, the capacity of small FDM-FM-FDMA carriers cannot be increased by over deviation, because of the cross talks among the carrier. A transponders carrying 6000 SSB-AM-FDMA channels can be accessed, say by 4 earth stations with 1500 channels, each with no loss in capacity. On the other hand a four-carrier compounded FDM-FM-FDMA transponder can carry about 1500 channels, therefore the high power amplifier in earth stations always implies some sort of redundancy configuration. The most basic redundancy configuration is the 1:1 redundancy.

3.7.1 Advantages

1. Simple algorithmically and from a hardware standpoint.
2. Fairly efficient when the number stations is small and the traffic is uniformly constant.

3.7.2 Disadvantages

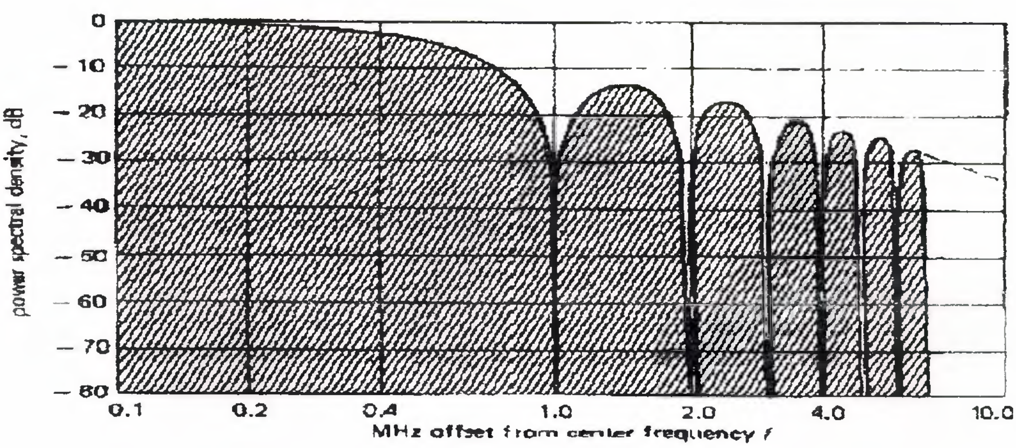
Not conducive to varying station population.

1. If traffic is bursty, bandwidth is wasted.
2. Interfrequency protection bands waste bandwidth.
3. No broadcast capability.

3.8 FDMA Channel Formats

The format of the frequency channel utilized for FDMA depends on signal distortion, adjacent channel interference, and inter-modulation effects caused by the satellite transponder nonlinearities. Following Figure shows a simplified FDMA format for a single channel of a satellite transponder. Each FDMA carrier can either carry a multiplexed set of user data streams, or it can carry only a single user's bit stream as in the SCPC system is described.The carriers can either be destination oriented or a single carrier can carry data destined for several receive earth stations. Guard bands must be used between adjacent frequency channels to minimize adjacent channel interference and these, of course, reduce the frequency utilization efficiency of the transponder channel. The required size of the guard band depends in part on the residual sidebands in each transmitted signal. Following figure shows the power spectral density of a QPSK signal at 1M symbol/sec (2M bps).

Graph 3.2: Power spectrum of QPSK



Transmission filters can be employed to cut off the signal spectrum at IF bandwidths between 1 and 2 MHz. The smaller bandwidths must utilize some form of equalization. However, these sidebands can build back up when the signal is fed through a non-linearity and envelope fluctuations produced by filtering are reduced. The guard band between adjacent frequencies must also account for the frequency drifts of the oscillators controlling the signal center frequencies at the satellite and earth station frequency translators. Doppler shirts of satellites that are not perfectly synchronized can also be significant for very low data rate transmissions. Satellite beacons used for antenna tracking or pilot signals can be used to reduce this frequency uncertainty if the beacon frequency is coherently related to the translation frequency.

4. TIME DIVISION MULTIPLE ACCESS

Time Division Multiple Access (TDMA) protocols used in broadcast bus communications for embedded systems. TDMA protocols have the potential to be both simple and effective for embedded system applications. In particular. TDMA is at its best when providing highly efficient use of bandwidth for a well-characterized, periodic communication traffic workload as found in many embedded systems. Additionally, the simplicity of TDMA lends itself well to embedded systems with limited hardware resources at each node. TDMA also avoids many subtle failure modes associated with more complex protocols, such as duplicate tokens on token bus systems. TDMA can have low protocol overhead if the multiplexed time slices are well balanced with respect to node workloads. And, TDMA does not require collision detection circuitry, which can be difficult or costly to implement in embedded systems.

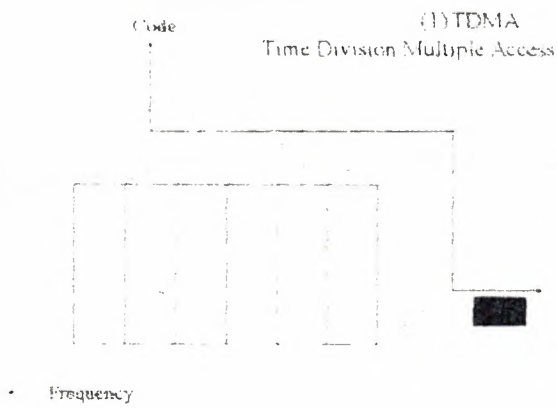


Figure 4.1: Frame of time division multiplex

Unfortunately, it is often difficult to actually use TDMA in practice because of reliability and cost concerns. As described later, classical TDMA uses a single bus-master node to synchronize communications. In many embedded systems, single points of failure are unacceptable; this is true not only in military and avionics systems, but also in many commercial systems, such as elevators and automobiles. Furthermore, a bus master increases size, weight, power consumption and cost. Alternatives to a single bus master seem to simply push complexity comparable to the master node into slave nodes. The key problem with using TDMA in practice is the need for a physical or logical bus master. This seems to have in practice limited TDMA to those applications that have a natural bus master, primarily satellite communications. We shall show a way to implement TDMA without using a bus master of any kind. Our technique permits nodes to come on-line and off-line freely, and is accomplished with a minimal increase over the logic complexity of slave nodes over classical TDMA. We feel that this will greatly increase the attractiveness of using TDMA to provide both simple and reliable embedded communications. Before presenting our new TDMA-based protocol, we first review classical TDMA, then discuss previous solutions to the problems caused by having a bus master.

4.1 Classical TDMA

In TDMA, bus access is controlled using a frame-based approach. As shown in Figure 4.2, transmissions on the bus are grouped into frames. Each frame starts with a frame sync, which is a unique bit pattern transmitted by the bus master. A frame gap following the frame sync is required with some transmission technologies (*e.g.*, transformer coupling) to allow time for the bus master's transmitter to return to a quiescent state.

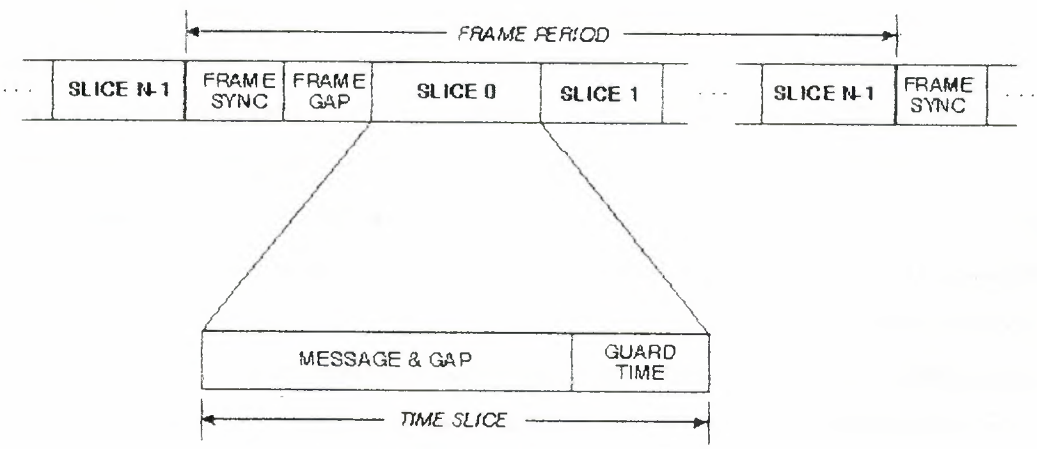


Figure 4.2: TDMA timeline.

N time slices follow the frame gap. In the simplest case, one time slice is assigned to each of *N* slave nodes. When a slave node detects frame sync, that slave node starts a countdown timer that expires at the start of its uniquely assigned time slice. When a slave node's time slice arrives, it transmits a message. In some implementations a gap period after the message is required to allow the transmitter to return to a quiescent state. After the message and gap, a guard time is allocated to accommodate timing skew among the oscillators of the nodes.

When all time slices have elapsed, the bus master transmits another frame sync message to restart the cycle. This frame sync serves as a central time reference point and is used to resynchronize the time bases of each slave node, eliminating cumulative time skew caused by oscillator speed inaccuracies over the duration of a frame. If a slave node has nothing to send during its time slice, or the slave node is off-line, its time slice elapses unused. There are several possible elaborations on this arrangement, such as allocating multiple time slices to nodes with heavy communication workloads and truncating unused slices.

4.2 Asynchronous Interfaces

Interface means, the point at which a connection is made between two elements so that they can work with one another. The Command-Line Interface typified by the MS-DOS A> or C> prompt, responds to commands typed by the user. The menu interface (also called Menu-Driven interface), used by many application programs such as Lotus 1-2-3, offers the user a choice of command words that can be activated by typing a letter, pressing a direction key, or pointing with a mouse. The graphical user interface, characteristic of the Apple Macintosh and of windowing programs, presents the user with a visual representation of some metaphor such as a desktop and allows the user to control not only menu choices but also the size, layout, and contents of one or more on-screen "windows" or working areas. At less visible software levels within the computer are other types of interfaces, such as those that enable an application to work with the operating system and those that enable an operating system to work with the computer's hardware. In hardware, interfaces are cards, plugs, and other devices that connect pieces of hardware with the computer so that information can be moved from place to place. There are, for example, standardized data-transfer interfaces, such as RS-232-C and SCSI, that enable connections between computers and printers, hard disks, and other devices.

In this type of connection no special frequency relationship between the TDMA system and the terrestrial networks is assumed. Slip-free operation can be achieved through the use of pulse stuffing on the transmit side to account for the difference between the DMA clock and the terrestrial clock, and pulse testifying on the receive side to restore the original data rate. Doppler buffers must again be employed on both transmit and receive sides to account for the effects of satellite motion. Figure shown below illustrates asynchronous interfaces. Each of these interfaces contains a stutter and a testifier as shown in Fig shown below. On the transmit side, the incoming terrestrial data stream is asynchronous; that is, its bit rate fluctuates around the nominal bit rate. The clock is recovered frequency by the clock recovery circuit. To make the data stream synchronous with the TDMA clock at frequency (or a sub multiple of fo, namely fo/m, where m is an integer), an elastic suffer is employed.

Asynchronous data is written into the elastic buffer by the write clock at a frequency of f k = R k, and synchronous data is read out of the elastic buffer by means of the TDMA clock. Since data must be written into the elastic buffer before it can be read out, the read clock must operate at a faster rate than the write clock; that is, the TDMA clock rate is set higher than the data clock rate. The frequency difference k is the stuffing rate. The read clock cannot be allowed to overtake the write clock to the extent that it attempts to read a bit that is not yet in the buffer. To prevent this situation, the phase difference between the write and read clocks is determined by a phase comparator. When the phase difference between the clocks reaches a certain threshold, the stuff decision circuit generates a stuff request to make the read clock dwell for one additional time slot. As a result, one bit in the elastic buffer is read twice or, in effect, a dummy bit is stuffed into the data stream. Also, the stuff control bits are multiplexed to the data stream at precise intervals according to a framing scheme which allows identification of the stuffing bits on the receive side so that they can be removed from the data stream. The output of the stuffer is a data stream operated at the TDMA clock rate fo or at a bit rate of Ro =fo bits per second.

On the receive side, the synchronous data stream at bit rate Ro is received by the testifier. By detecting the stuff control bits, the stuffed bits can be removed from the data stream. Because of removal of the stuffed bits the write clock is jittered. By generating a read clock at the average frequency of the write clock, the effect of jitter is smoothed and the data is read out of the elastic buffer with the same clock frequency with which it enters the stuffer on the transmit side. Frequency control of the read clock is achieved by a phase-locked loop. The output of the testifier is an asynchronous data stream at a nominal bit rate per second operated at the nominal in a synchronous operation; the digital terrestrial network clock is synchronized with the TDMA local clock. This local clock is phase-locked to the reference station clock recovered from detection of the reference burst's unique word. Each terrestrial interface accepts an incoming data stream from the digital terrestrial network at a rate of R k bits per second and delivers an outgoing data stream at a rate of R k bits per second to the terrestrial network

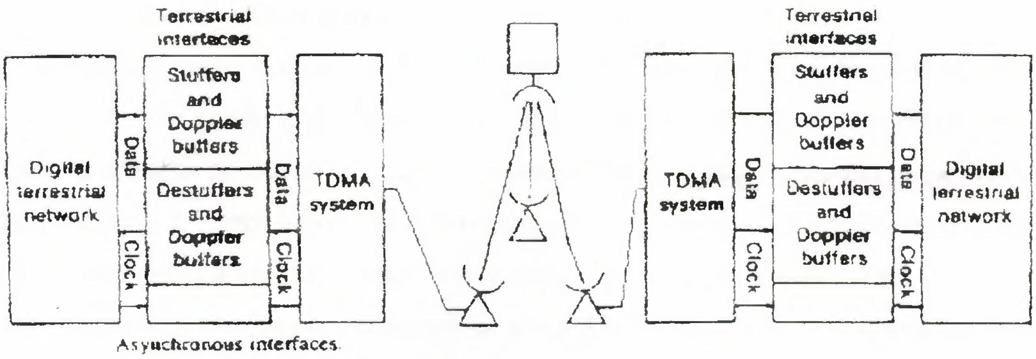


Figure 4.3: TDMA clock rate

Assume that each terrestrial interface is designed to accommodate a T1 carrier at a bit rate of Rk=1.544 Mbps and that the TDMA local clock frequency is fo = 44.776 MHz; then the terrestrial interface clock can be obtained as fk=fo/29=1.544 MHz. The terrestrial interface multiplexes the data stream and the clock and transmits them to the digital terrestrial network where the clock f k is extracted from the data stream and used to generate the incoming data stream (from the terrestrial network to the TDMA system). Thus the incoming data stream is also synchronized with the TDMA clock. Because the outgoing data stream at the terrestrial interface is synchronized with the TDMA local clock phase-locked to the reference station clock no Doppler buffet- is needed on the receive side of the terrestrial interface. However, because of periodic modifications of the transmit frame using the transmit frame delay D.

4.3 The Different Guises of Bus Masters

All previous implementations of TDMA seem to use either a permanent or transient bus master of some kind. Unfortunately, use of a bus master tends to introduce complexities and costs that detract from TDMA's advantages. Before proposing a solution, we shall review what we believe to be the common approaches to dealing with bus mastership in TDMA: static allocation of mastership, dynamic allocation of mastership, and initial allocation of mastership with stable time bases. Doppler buffers are needed on the transmit side. Figure illustrates synchronous interfaces for a TDMA system. Note that in this mode of operation the PCM frame (125ms} in the digital terrestrial network and the TDMA frame may not be synchronized, although the data clocks are synchronized with the receive TDMA clock. That is why Doppler buffers are employed on the transmit side. Doppler Effect, in physics, the apparent variation in frequency of any emitted wave, such as a wave of light or sound, as the source of the wave approaches or moves away from an observer. The effect takes its name from the Austrian physicist Christian Johann Doppler, who first stated the physical principle in 1842. Doppler's principle explains why, if a source of sound of a constant pitch is moving towards an observer, the sound seems higher in pitch, whereas if the source is moving away it seems lower. This change in pitch can be heard by an observer listening to the whistle of an express train from a station platform or another train. The lines in the spectrum of a luminous body such as a star are similarly shifted towards the violet if the distance between the star and the Earth is decreasing and towards the red if the distance is increasing. By measuring this shift, the relative motion of the Earth and the star can be calculated.

4.3.1 Static Allocation of Mastership

Static allocation of bus mastership is the classical TDMA approach [6]. In the simplest case, a dedicated bus master is used. An alternative is to replicate the extra logic for mastership within at least one slave node, then designate that node as both a slave and the bus master. For example, node 0 could always be the bus master. The problem with static allocation is obvious: whether the bus master is dedicated or combined with a slave node, failure of the bus master causes network failure.

4.3.2 Dynamic Allocation of Mastership

An alternative scheme is to designate a bus master among the operational slave nodes during network initialization. Thus, rather than statically designating a particular node as the bus master, the first node to be turned on could become the bus master. Once a bus master takes control, it remains in control until it fails. If a bus master fails, another slave node may detect the failure and become bus master itself (a similar idea is described in).

The problem with dynamic allocation of mastership is that if two nodes are turned on almost simultaneously (within one bus propagation delay &TAU; $_{pd}$), a conflict arises. Some arbitration mechanism must be invoked that designates one, and only one, bus master before proper network operation can proceed. This arbitration mechanism increases slave node complexity, and seems a high price to pay for a function that is only used when the system is reset. The arbitration mechanism is often complicated by the fact that collision detection circuitry is not available due to cost and practicality constraints. Even with dynamic allocation of mastership, the current master still constitutes a single point of failure. If extra logic is included to facilitate automatic network resets and re-designation of a bus master, single-point failures can be minimized. However, the resultant node design is much more complicated than the original TDMA slave node.

4.3.3 Initial Allocation of Mastership with Stable Time Bases

A somewhat different approach is taken by the ARINC-629 protocol. [4] In ARINC-629, there is no single bus master during normal operation. Rather than using a frame sync from a bus master, each node keeps track of time slices as they elapse, whether there are transmissions or not. Frame starts are not explicitly delineated by transmission events. In order to limit the effects of accumulated time-base skew between nodes, two crosschecked time sources are incorporated into each node, and nodes resynchronize at the end of every transmitted message. ARINC-629 implementations must ensure that messages are sent occasionally to avoid excessive timing skew, even with redundant oscillators at each node. With ARINC-629, there must still be some initial synchronization event to start operation. This is done with an arbitration scheme that must deal with potential message collisions, just as in the case of dynamic allocation of mastership. The difference with the use of stable time bases is that after the initial master gains control (by issuing a non-colliding message that all other nodes synchronize to), mastership is then irrelevant for further operation.

The disadvantages of initial allocation of mastership with stable time bases are that logic for an initial arbitration scheme must be included, and very stable time bases must be used to minimize oscillator skew over the longest possible time between messages on the network. One could reduce the effects of oscillator skew by generating dummy messages periodically, but such messages would have to be sent sparingly to gain the benefits of ARINC-629's variable-width time slice feature that compresses unused time slices to increase efficiency. A dummy message scheme would also resemble a dynamically allocated master arrangement, with the attendant complexity increase and failure modes. A further problem with using stable time bases instead of frame syncs is that if a node is reset or brought on-line after the bus has started operation, there is no predictable reference for determining where the newly activated node's time slice begins; and no guarantee of how long the newly activated node will have to wait before some recognizable signal is transmitted by other nodes on the bus.

4.4 Burst Time Plan

As discussed before, in a TDMA network a traffic station transmits its bursts on time to their allocated positions in the frame at the satellite transponder according to a transmit Burst time plan and receives bursts in the frame returned by the satellite transponder according to a receive burst time plan. The burst time plan is thus a map that indicates the position and length of bursts in the frame and also the position and length of information sub bursts within a burst. Since bursts and sub bursts carry traffic (voice, data, video) between stations, the burst time plan is simply the traffic assignment within a frame. If the total traffic of a TDMA network exceeds the capacity of one transponder, the network has to operate with more than one transponder. This means that a traffic station might transmit bursts to more than one transponder and might be required to receive bursts from more than one transponder (transponder hopping). In such a multiple-transponder operation, the burst time plan is the assignment of traffic to transponders and time ordering of the assigned traffic within a frame.

4.5 TDMA Burst Structure

In general the structure of the reference burst and the traffic burst arc as shown schematically in Fig. 4.4.

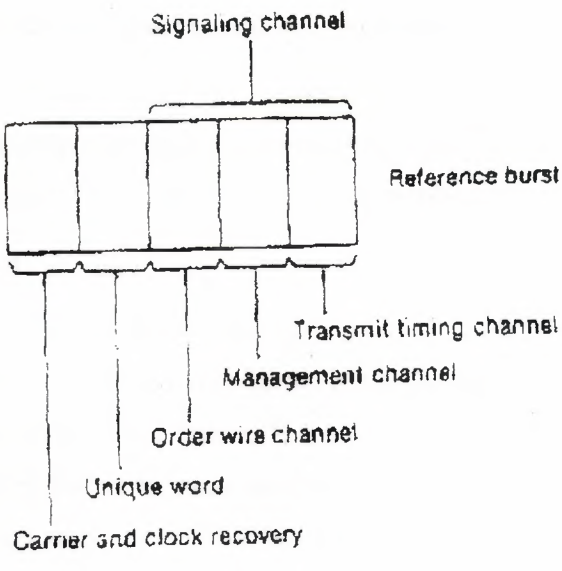


Figure 4.4: TDMA Burst Structure

In the traffic burst. information bits are preceded by a group of bus referred to as a preamble that is used to synchronize the burst and to carry management and control information. The reference burst contains only the preamble, that is. no traffic data. Normally the preamble consists of three contiguous parts: the carrier. and clock recover) sequence (CCR), the unique word (UW) and the signaling channel.

4.5.1 Carder and Clock Recovery Sequence

Each burst begins with a sequence of bits or symbols as in figure 4.5 below.

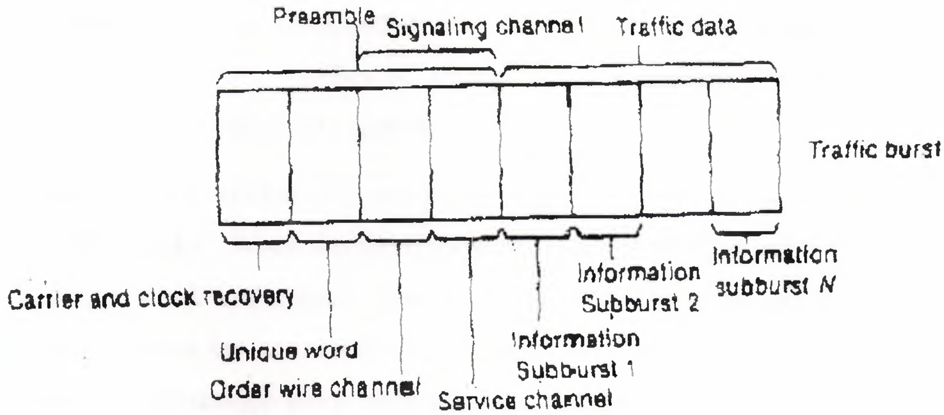


Figure 4.5: Sequence of bits

Which enable the earth station demodulator to recover the carrier phase and regenerate the bit or symbol timing clock for data demodulation. Normally, the length of the carrier and clock recovery sequence depends on the carrier-to-noise ratio at the input of the demodulator and the acquisition range (carrier frequency uncertainty).

A high carrier to-noise-ratio and a small acquisition range require a short CCR sequence, and vice versa. Typically, a high-bit-rate TDMA system requires a long CCR sequence, fore example. 300 to 400 bits (150-200 symbols for 120-Mbps TDMA.

4.5.2 Unique Word

The unique word that follows the carrier and clock recovery sequence is Used in the reference burst to provide the receive frame timing that allows a station to locate the position of a traffic burst in the frame. The unique word in the traffic burst marks The time of occurrence of the traffic burst and provides the receive burst timing that allows the station to extract only the wanted sub bursts within the traffic burst. The unique word is a sequence of ones and zeros selected to exhibit good correlation properties to enhance detection.

At the demodulator, the unique word enters a unique word detector, like the digital correlate, where it is correlated with a stored pattern of itself. The correlator consists of two N-stage shift registers (where N is the length of the unique word), N modulo-2 adders, a summer, and a threshold detector. The received data is shifted in the shift register in synchronization with the data clock rate. Each stage in the shift register is applied to a modulo-2 adder whose out- put is a logical zero when the data bh or symbol in the stage is in agreement with the stored unique word bit or symbol in the same position. All the modulo-2 adder outputs are summed, and the sum is compared to a preset threshold by the threshold detector. The output of the summer is thus a step function representing the number of agreements or disagreements between the input data and the stored unique word pattern.

The maximum number of errors allowed in the unique word detection is called the detection threshold E. When the correlation errors are equal to or below E, the detection of the unique word is declared. The unique word detection occurs at the instant of reception of the last bit or symbol of the unique word and is used to mark the receive frame timing if the unique word belongs to the primary reference burst, or to mark the receive traffic. Burst timing if the unique word belongs to the traffic burst. The position of every burst in the frame is defined with respect to the receive frame timing, and the position of every sub burst in a traffic burst is defined with respect to the burst's receive burst timing. It is seen that accurate detection of the unique word is of utmost importance in a TDMA system. For example, when the unique word of a traffic burst is missed, the entire traffic burst is lost. This causes impulses or clicks in voice transmission. In data transmission, a block is lost and consequently the bit error rate is increased. A false detection of the primary reference burst unique word generates the wrong receive frame timing and consequently incorrect transmit frame timing, causing the earth station to transmit out of synchronization and resulting in overlapping with other bursts at the satellite. A false detection is generated whenever data or noise agrees with the stored unique word pattern to the extent that the number of bits or symbols in disagreement fall below the detection threshold e A unique word miss occurs when channel noise causes more than E errors in the receive unique word sequence, making the number of bits or symbols in disagreement exceed the detection threshold e. In general, for a given unique word length, increasing the detection threshold E makes the miss detection probability smaller but raises the false detection probability.

4.5.3 Signaling Channel

In general the signaling channel of the reference burst consists of the following sub bursts:

1. An order wire channel carrying voice (telephone), and data (teletype) traffic via which instructions are passed to and from earth stations. Order wire is a term used in manual telephone switching to describe a circuit on which operators and maintenance personnel can talk to one another. Operators use the order wire for placing calls.

2. A management channel, which is sent by the reference stations to all traffic stations carrying frame management instructions such as, burst time plan changes. The burst time plan describes the coordination of traffic between stations. It identifies the boundaries of the time slots of the frame allocated to the stations, that is, burst positions. It also identifies the position, length, and source or destination stations corresponding to sub bursts in the bursts. This channel also carries monitoring and control messages to the traffic stations when the reference station wants to obtain a status report (monitoring) and/or to control the switchover of subsystems at the traffic stations remotely.

3. A transmit timing channel carrying acquisition and synchronization Information to the traffic stations which enables them to adjust their transmit burst timing so that transmitted bursts arrive at the satellite transponder within the correct time slots in the TDMA frame. It also carries the status codes, which allow the traffic stations to identify the primary reference burst and the secondary reference burst from RB1 and RB2

The signaling channel of the traffic bursts consists of the following sub bursts:

a. An order wire channel, which is the same as the reference burst order wire channel.
b. A service channel carrying the traffic station's status to the reference station, or other information such as the high bit error rate and unique word loss alarms to other traffic stations.

Besides these sub bursts in the preamble, both reference and traffic bursts can carry additional sub bursts containing the frame identification number (for frame management purposes), station identification number, and type of transmitting bursts (primary reference burst, secondary reference burst, traffic burst). Different types of unique words can be employed to provide burst identification.

4.5.4 Traffic Data

Traffic information is carried by the traffic burst immediately following the preamble. The length of a traffic sub burst depends primarily on the' type of services and the total number of channels required for each service being supported in the burst. This portion contains information from the calling user being communicated to the called user, whether it will be voice, data, video, or facsimile signals. The information for each channel is transmitted as a Continuous sub burst. The size of each sub burst may be selected to be any number of bits to specifically accommodate the actual speed of the voice, data. Video, or facsimile signal. For example, one PCM voice channel is equivalent to 64 kbps; if the frame length T i= 1 ms, the resulting sub burst of one PCM voice channel is 128 bits long. Each station in the TDMA network normally can transmit many traffic bursts containing different numbers of sub bursts per frame and is also capable of receiving many traffic bursts or sub bursts per frame.

4.6 The J-TDMA Protocol

In order to avoid the problems of other TDMA protocols, we propose a new scheme that completely eliminates the need for a bus master. Because the protocol is based on using a "jam" signal as the frame sync, we call it J-TDMA. Classically, a TDMA bus master's frame sync is used to avoid collisions among slave nodes by limiting accumulated timing skew. This resynchronization at the start of each frame, combined with a guard time at the end of each time slice, prevents slave node transmissions from overlapping. Typically, the frame sync signal consists of a unique waveform pattern such as an intentionally misplaced signal transition edge or a long sequence of ones that is otherwise illegal in a bit-stuffed transmission scheme.

The reason that collisions are undesirable in TDMA is that they are difficult or expensive to detect. If two transmitters were to attempt to send frame syncs concurrently, they might be enough out of phase to cause waveform interference between high and low physical signal levels on some or all of the bus as their signals propagates. This interference could cause some receivers to miss some or the entire frame sync message. Even on systems where such interference might not be a problem at the physical level, TDMA designs traditionally designate a bus master. The key idea of J-TDMA is to use a nondestructive frame sync signal, so that more than one transmitter can send frame sync without adverse interaction among signals. While most other TDMA protocols focus on having single bus master issue frame syncs, J-TDMA is designed to tolerate multiple overlapping frame sync transmissions. Thus, the issue of establishing a unique bus master is rendered moot in J-TDMA.

An excellent candidate for such a frame sync signal corresponds to a "jam signal" used to enforce recognition of collisions in collision-based protocols (*e.g.*, [2]). For example, in a base band multimode fiber optic system, one or more transmitters can jam by emitting light (base band "on") for a period of several bit times. As another example, current-mode transformer coupled systems can jam by having one or more transmitters assert a physical "high" value for longer than a bit time. In general, any signal, which nondestructively propagates throughout the communication medium, can serve as a jam signal. No data need be communicated by the jam signal -- only the presence of a jam signal need be detected in order to establish a synchronization event. J-TDMA follows the same time sequence shown in Figure 4.6 for TDMA. The major difference is that more than one node may issue overlapping frame sync signals. Figure 4.6 gives a Finite State Machine (FSM) diagram for the logic contained in each node when implementing J-TDMA. In the description we shall use "frame sync" to mean the logical operation of establishing a time reference, and "jam" to mean the physical act of transmitting a jam signal to implement a frame sync operation. Initialization is handled by having each newly activated node wait for an entire frame period to determine if the network is active. If frame sync is detected, the node joins the active network. If no signals are detected for an entire frame period, then the node is the only active node on the bus, so it asserts a frame sync to start bus operation. It is permissible for multiple nodes to assert this first frame sync without arbitrating for initial mastership, because multiple jumpers are allowed.

In normal operation, each node waits for its assigned slot interval beyond the frame sync, and sends a message at the appropriate time. It then waits until the anticipated end of the frame time, then emits frame sync. If a node detects frame sync before its computed end of frame time, it simply accepts the incoming frame sync signal as the start of a frame without emitting its own frame sync. It is possible that multiple nodes will start transmitting frame syncs within a propagation delay of each other: because they won't receive other frame syncs until up to a propagation delay after other nodes assert them. With this method, the nodes with fast oscillators will assert frame syncs, while other nodes resynchronize to them. As nodes come on-line and off-line, and components age, the fastest operating nodes will set the frame period.

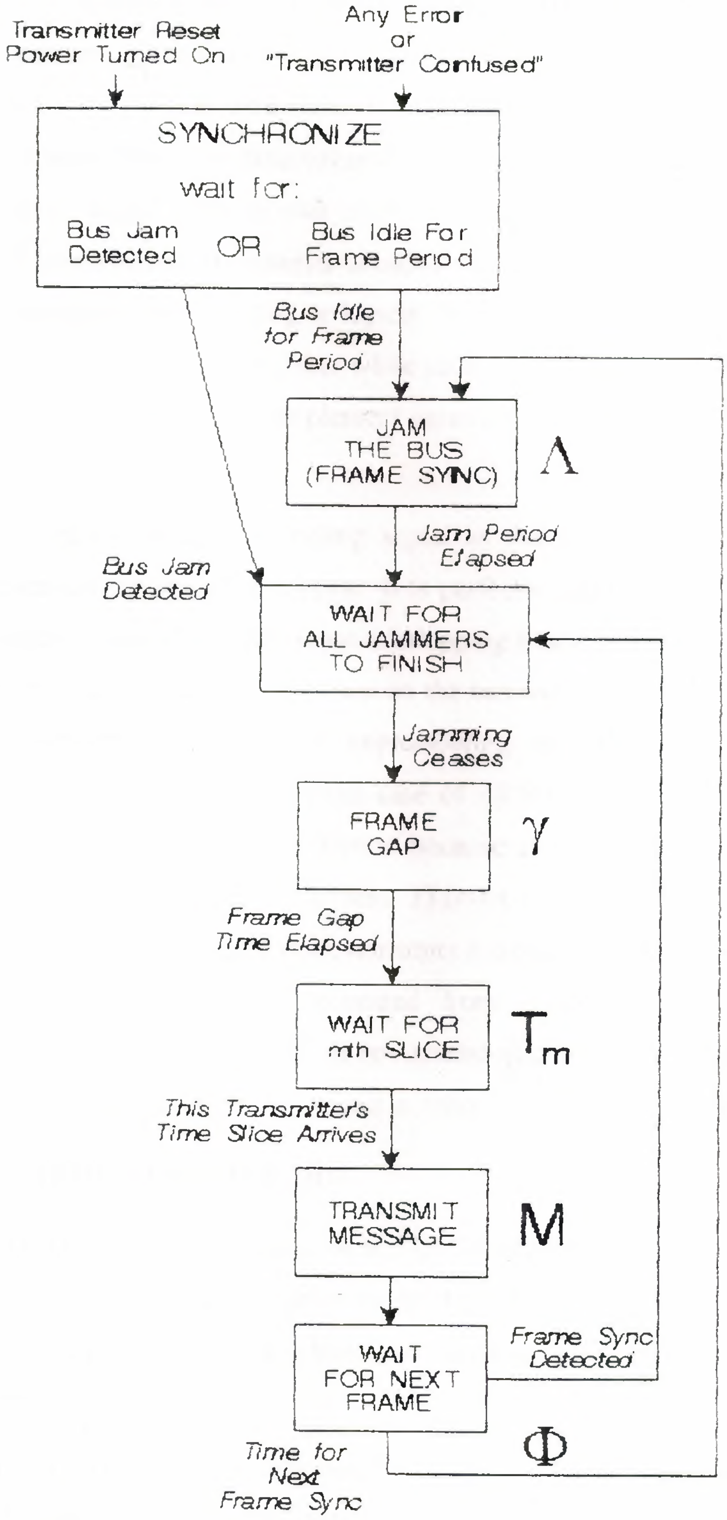


Figure 4.6: Finite State Machine for J-TDMA protocol.

Detecting a jam signal is inherently easier than detecting a collision, because during jamming all transmitters are asserting mutually non-destructive waveforms, whereas during a collision between arbitrary data transmissions the waveforms may destructively interfere. Care must be taken to ensure that communications bus noise is unlikely to falsely trigger jam detection; in most cases this simply means that the jam signal must be longer than a bit time rather than shorter. A jam signal is not the same as a "bit dominance" signal such as that used by the Controller Area Network (CAN) protocol. In bit dominance a transmitter broadcasting a logical "1" must dominate over some other transmitter broadcasting a logical "0". For jamming, it is sufficient that transmitters not interfere with each other while each is broadcasting only a "high" level. So, bit dominance may be used to implement jamming, but jamming does not require a full bit dominance capability.

Once we decide to use a jamming signal as the frame sync, all questions of establishing a unique bus master disappear. It is perfectly acceptable for multiple nodes to be designated as bus masters and issue overlapping frame sync signals, because they won't interfere with each other: any receiver on the bus will detect only single elongated frame sync. Furthermore, issues of implementing an arbitration mechanism to momentarily pick a bus master (as in the case of ARINC-629) also disappear. There truly never needs to be a unique bus master, because all nodes can assert frame syncs without concern for collision. In all fairness, JTDMA still has a potential single-point failure mode: jabbering. If a single node transmits a continuous jamming signal or data transmission, other nodes will be prevented from using the communication bus. However, this failure mode is inherent in any shared-medium communications scheme, and so is no worse a problem than that found in other media access protocols.

4.7 TDMA Super frame Structure

The two most critical functions in a TDMA network are control of the burst position in the frame and coordination of the traffic between stations in such a way that any rearrangement of the position and length of bursts does not cause service disruption or burst overlapping.

Control of the position of bursts may be carried out by the reference station using the transmit liming channel, while coordination of traffic is achieved through the management channel of the reference burst. To provide control and coordination, the reference station has to address all the traffic stations in the network. If there are N stations to be addressed in the network, there will be N messages in the transmit timing channel and N messages in the management channel of the reference burst, Furthermore, to provide almost error-free communication for these critical control and coordination messages, some form of coding is normally employed. The most commonly used coding for these channels is the 8:1 redundancy-coding algorithm where an information bit is repeated eight times according to a predetermined pattern and then decoded using majority decision logic at the receive end.

This effectively increases the time slot allocated to each message eight times and further reduces the frame efficiency. The same reasoning applies to the service channel of the traffic bursts. In order to reduce the length of the preamble of the reference bursts and the traffic bursts, the reference station can send one message to one station per frame instead of N messages to N stations per frame. To address N stations in the network, the process takes N frames. For example; the reference station in frame 1 addresses station 1, Station 2 by the one in frame 2, so on, and finally station N by the one in frame N. The procedure is repeated in the same fashion for the next N frames until completion. Similarly, if The status report sent by the traffic station to the reference station, or other information sent to other traffic stations, is sent over N frames and repeated until completion, the length of traffic burst preamble will also be reduced, hence the frame efficiency will be increased.

In this way, N frames can be put into one group called a super frame, where N is the number of stations addressed by the reference station as shown in figure. To identify the frames in a super frame, a frame identification number may be carried in the management channel or in a separate channel in the reference burst for each frame. Normally the identification number of frame 1 serves as the super frame marker. Alternatively, different unique words can be employed by the reference bursts and traffic bursts to distinguish the super frame marker from the frame markers. When the number of stations N in the network is fixed, or its maximum is known, it is easy to design the service channel of the traffic bursts so that its message can be transmitted over N frames. For example, any message transmitted by the service channel of the traffic bursts is limited to a maximum of 40 bits. If the 8:1 redundancy-coding algorithm is used for the message, it will take 320 bits to transmit it. Suppose N = 10 (i.e., a super frame consists of 10 frames): then a super frame would be needed to transmit the 320-

bit message with 32 bits per frame. That is, the service channel occupies a time slot of only 32 bits. Although the rate of message data transmission is now only 4 bits per frame, the frame efficiency is increased significantly as compared to transmitting 320 bits per frame (40 bits of message data per frame).

When the number of stations N in the network is variable, that is, the network can grow, and if demand assignment is employed it might be appropriate to transmit the messages in the service channel of the traffic bursts and demand assignment messages in a separate super frame short burst (SSB) at the super frame rate. That is, each of the N stations in the network transmits a super frame short burst once per super frame. In other words, each frame of a super frame contains a super frame short burst from a designated station. For the above example, the super frame short burst would be allocated a time slot of 320 bits for a 40-bit message with 8:1 redundancy coding. Note that message data rate is still 40 bits per super frame as in the case where a service channel with 4 bits of message data per frame is used in a traffic burst. The advantage of putting the service channel in the super frame short burst instead of in the traffic burst is to increase the frame efficiency when a station transmits more than one traffic burst per frame. Since the messages in the service channel of all the traffic bursts in the same frame that originate from the same station are normally identical for ease of design. The redundancy of messages reduces the frame of efficiency; a typical super frame short burst.

4.8 Frame Acquisitions And Synchronization

In 1884 Paul Nipkow, a German engineer, produced an early version of mechanical TV, which provided a primitive solution to the problem of scanning. Nipkow drilled a spiral of holes in a disc, which was made to rotate. Light passing through these holes registered on a selenium cell. A similar disc rotated at the receiving end of the system, and the light projected by the selenium cell reproduced the original shape silhouetted by the light. Besides scanning, the Nipkow system also had the vital feature of synchronization, in that the two discs rotated at the same speed. In Britain, the Scottish engineer John Logie Baird is often credited with the invention of TV. In fact, although Baird was responsible for some important early innovations, and provided the first public demonstration of a 30-line image in 1926, his mechanical system was superseded by electronic systems in the 1930s. At the center of developments in electronic TV was the cathode ray tube, developed in the late 19th century. This is simply a vacuum tube inside which a beam of high-energy electrons focuses on a fluorescent screen to give light. An early Russian innovator, Boris Rozing, modified the cathode ray tube to display images from a mechanical scanner in 1907. It was in the 1920s that developments in TV began to precede quickly. The immense success of radio in the post-1918 period led companies to realize that great profits could be made from the manufacture of communications goods. During this era, TV began to be conceived of as a broadcasting technology rather than as a form of telecommunications, as people began to pursue new forms of leisure activity within the home.

Synchronization deals with the research, design, integration, and application of circuits and devices used in the transmission and processing of information. Virtually unknown just a few decades ago, computer engineering is now the most rapidly growing field, and deals with the design and manufacture of memory systems, of central processing units, and of peripheral devices. Circuits are designed to perform specific tasks, such as amplifying electronic signals, adding binary numbers, and demodulating radio signals to recover the information they carry. Circuits are also used to generate waveforms useful for synchronization and timing, as found in television broadcasting techniques, and for correcting errors in digital information, as in telecommunications. In TDMA system, a traffic station must perform two functions:

On the receive side, the traffic station must be able to receive traffic bursts addressed to it from a satellite transponder (or transponders) periodically every frame. On the transmit side, the traffic station must be able to transmit traffic bursts destined to other stations periodically every frame in such a way that the bursts arrive at a satellite transponder (or transponders) without overlapping with bursts from other traffic stations. As mentioned before, the timing reference in a TDMA system is provided by the primary reference burst. By detecting the unique word of the primary reference burst, the traffic station can establish the receive frame timing (RFT) which is defined as The instant of occurrence of the last bit or symbol of the primary reference burst's unique word. The technical proficiency of the movements. For routines, two panels of judges mark technical merit and artistic impression. Technical marks are given for execution, synchronization, and difficulty of the movements, and marks for artistic impression are awarded for choreography, musical interpretation, and manner of presentation. In all sections, marks are given out of ten.

Also, the last bit or symbol of the traffic burst's unique word marks its receive burst timing (RBT). Since the receive frame timing marks the start of a received frame, the position of a traffic burst in a received frame is determined by the offset between the receive frame timing and the receive burst timing. This offset (in bits or symbols) is contained in a receive burst time plan which is stored in the foreground memory of the traffic station. Using the receive burst time plan, the traffic station can extract any traffic burst intended for it in a received frame. To transmit a traffic burst so that it arrives at the satellite transponder within the allocated position in the frame, the traffic station must establish a transmit frame timing (TFT), which marks the start of the station's transmit frame, and a transmit burst riming (TBT), which marks the start of transmission of the traffic burst to the satellite. The position of the traffic burst in a transmitted frame is determined by the of' l'sel between the transmit frame timing and the transmit burst timing. This offset is contained in a transmit burst time plan stored in the foreground Memory of the traffic station. If the traffic station transmits a traffic burst at the transmit frame timing, it will arrive at the satellite transponder at the same time as the primary reference burst that marks the start of a frame at the transponder. Any traffic burst transmitted at its transmit bunt timing will fall into its appropriate position in the TDMA frame at the transponder. In this way, traffic bursts from many stations that access a particular transponder will fall into their reassigned positions in the frame at the transponder and burst overlapping will not occur.

CONCLUSIONS

In Satellite Communication System we know several different forms of communications although we know that there is an uplink from a ground-base station to the satellite and a downlink from satellite back to ground modulated carriers in the form of electromagnetic field, which are propagated up to the satellite. The satellite has an ability to retransmit the modulated carrier as a downlink to specified earth station, which was collected from impinging electromagnetic field. Transponder output power levels are directly related to available primary power. The load the efficiency, the less the carrier power for the given amount of primary power, or conversely the more primary power to achieve desire downlink carrier power.

The entire transponder must provide the required overall gain needed to multiply the uplink power level to that of the downlink. Transponders require intermediate amplification to achieve the power level suitably matched to the capability of the high power downlink amplifier. A satellite that merely relays the uplink carrier as a downlink is referred to as a relay satellite or repeater satellite system. Commonly, since the satellite transmits the downlink by responding to the uplink, it is also called a transponder

In this project I have reminded again the same idea of communication protocols, which we call J-TDMA. By using a jamming signal, one or more nodes may assert frame sync signals without destructively interfering, eliminating the need for a bus master. I have also shown equations for system parameters that account for variations in oscillator accuracy, enabling implementers to build systems with less accurate and less expensive time bases. This shows that how to build significantly simpler and less expensive TDMA systems, while at the same time permitting more flexible and robust system design.

REFERENCES

1. Telecommunications, by Prof. Dr. Fakreddin Mamedov.

2. Satellite Communications, Second Edition by Robert M. Gagliardi.

3. Digital Satellite Communications, Second Edition by Tri T. Ha.

4. Satellite Communications, by David W.E. Rees

5. Robert Bosch GmbH (1991), CAN Specification, Ver. 2.0, Stuttgart, Germany, September.

6. P. Gburzynski & P. Rudnicki (1989) A virtual token protocol for bus networks: correctness and performance, INFOR 27(2): 183-205, May.

7. H. W. Lee & L. Liang (1990), A Generalized Analysis of Message Delay in STDMA, Computer Networks and ISDN systems, 19(1), September.

8. National Semiconductor Corp. (1992), ARINC 629 Communication Integrated Circuit Data Sheet, Rev. 2.0.

9. Scientific and Engineering Software, Inc. (1992), SES/workbench Reference Manual Release 2.1, Austin, Texas.

10. W.S. Stallings (1991), Data and Computer Communications, 3rd ed., Macmillan, New York.