TRANSNAV
http://www.transnav.eu
the International Journal
on Marine Navigation
and Safety of Sea Transportation
Volume 14
Number 4
December 2020

DOI: 10.12716/1001.14.04.04

Analyses of Frequency Division Multiple Access (FDMA) Schemes for Global Mobile Satellite Communications (GMSC)

D.S. Ilcev
Durban University of Technology, Durban, South Africa

ABSTRACT: This paper introduces analyzes of the Frequency Division Multiple Access (FDMA) applicable in Global Mobile Satellite Communications (GMSC). In satellite systems, as a rule, especially in GMSC many users are active at the same time. The problem of simultaneous communications between many single or multipoint mobile satellite users, however, can be solved by using the Multiple Access Technique (MAT) scheme. Since the resources of the systems such as the transmitting power and the bandwidth are limited, it is advisable to use the channels with a complete charge and to create different MAT schemes to the channel. This generates a problem of summation and separation of signals in the transmission and reception parts, respectively. Deciding this problem consists in the development of orthogonal channels of transmission in order to divide signals from various users unambiguously on the reception part.

1 INTRODUCTION

Fundamental to any radio transmission link is the decision to use either analog or digital technology. Clearly, digital transmission technology is used wherever possible, but where radio transmission is concerned, the carrier waves are always analog in nature. In recent days, a digital signal is in most cases superimposed on the analog carrier. Thus, frequency-modulated systems are still in service in many parts of the world, especially for TV transmission, but the focus here will be on digital techniques. In practice, a satellite transponder can be shared primarily in three ways, each defined by a Multiple Access Technique (MAT): (1) Frequency Division Multiple Access (FDMA), 2. Time Division Multiple Access (TDMA), and (3) Code Division Multiple Access (CDMA). The satellite band allocation, about 500 MHz at C-band, can be divided up into numerous single voice channels of equal bandwidth by a multiplexed signal containing many voice band channels, or by a digital bitstream containing a combination of voice and variable bit rate data. These options lead to the terms FDMA and TDMA techniques so that each conversation is carried on a different frequency band.

The FDMA scheme is a technique built on the Frequency Division Multiplexing (FDM) method. This technique can be considered to be the oldest and the simplest form of multiplexing, which is used very commonly in many technical fields such as the telephone and commercial radio and television broadcasting industries. The FDMA technique can be applied for both digital and analog systems, although FDMA is widely used in the analog communication systems. The FDMA technique has spectral efficiency, because of the transmission rate which is quite close to the maximum rate that is needed by the user. As a result, FDMA can be considered to be suitable for users who don't have any serious problem with traffic in the transmission, and most of the users' work is predictable. Therefore, in unequal amounts of traffic generated by users, FDMA can make some modifications to deal and handle such a problem by allocating and regulating the bandwidth with respect to the amount of traffic. Since the transmission in communication systems is continuous, FDMA will need frequencies that can deal with different carriers with different channels. But FDMA doesn't have the capability to work with signals on multiple frequency channels. Therefore, it is almost impossible to allocate many channels for each user at the same time. In general, FDMA is suitable for many applications with suitable data types such as voice data.

Thus, in fixed and mobile satellite communication FDMA and Code Division Multiple Access (CDMA) are two common multiple access technologies that are widely used in various transmission and hybrid schemes. The FDMA technique is the first MAT scheme implemented on satellite communication and navigation networks. As stated, initially this modulation scheme was used in the analog technique, perhaps because it contains the FDM mode which is indeed the analog frequency division multiplexing technique. Before the digital revolution, all satellite systems used FDM signals which were frequency modulated onto a carrier within the FDMA bandwidth available. Nowadays, FDMA uses digital transmission packaging and is serving in modern satellite systems.

The FDMA scheme describes the way in which the information passes through the transponder. There can be many carriers and the bandwidth used by each carrier is a measure of the number of voice or data channels transmitted. At one extreme of the FDMA is used Multiple Channels Per Carrier (MCPC) and there is also Single Channel Per Carrier (SCPC), or a carrier might contain many channels in an TDM bit stream. In FDMA systems, intermodulation (IM) products created in the satellite transponder by the many carriers necessitate a reduction of the output amplifier output power to ensure that it operates in the linear region, well below its saturation value. This "back-off" results in a reduction of transmitted power and consequently the total number of channels that can be transmitted.

Therefore, the basic purpose of the FDMA technique in GMSC systems is to share the frequency resource among Mobile Earth Stations (MES) terminals by use of multiple frequency slots. Technically a frequency slot is occupied by a carrier modulated with the data rate, including Forward Error Correction (FEC) if necessary, wanted by a certain subscriber. A standard channel arrangement is to use one partial RF-band for downlink transmission from the Ground Earth Station (GES) to all MES terminals inside of satellite coverage, and another partial band (normally but not necessary of the same bandwidth) for uplink transmission from the MES to the GES terminals.

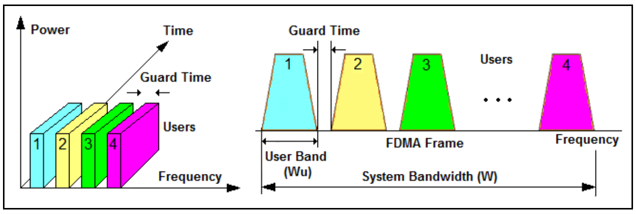

Figure 1. Frequency Division Multiple Access (FDMA) Techniques and FDMA Frame Structure

2 PRINCIPLES OF FDMA SCHEME

Both schemes, FDMA and TDMA are widely used for digital transmission, and these subjects are covered in wireless and satellite communication systems. Thus, the most common and first employed MAT scheme for satellite communication systems is the FDMA concept shown in Figure 1 (Left), where transmitting signals occupy non-overlapping frequency bands with a special guard band between signals to avoid interchannel interference. The bandwidth of a repeater channel is therefore divided into many sub-bands each assigned to the carrier transmitted by an GES terminal. The MES terminals transmit continuously and the channel transmits several carriers simultaneously at a series of different frequency bands. Because of interchannel interference, it is necessary to provide guard intervals between each band occupied by a carrier to allow for the imperfections of oscillator and filter devices. The downlink receiver (Rx) selects the required carrier in accordance with the appropriate frequency. When the satellite transponder is operating close to its saturation, nonlinear amplification produces intermodulation (IM) products, which may cause interference in the signals of other users. In order to reduce IM, it is necessary to operate the satellite transponder by reducing the total input power according to input back off and that the IF amplifier provides adequate filtering.

Broadly speaking, the FDMA sample shown in Figure 1 (Left) simply means splitting up an available frequency band into a specific number of channels, and the bandwidth of each channel depends on the type of information signals to be transmitted by users. After that, every user will be allocated with a special channel with a channel bandwidth of (30 kHz). These channels have a feature that the signals will be controlled by guard bands, which have a beneficial effect on decreasing the transmission impairments by avoiding any interference between channels. One pair of channels is used for fullduplex operation. Information to be transmitted is superimposed on a carrier at the channel center frequency. The information can be a composite of several information signals, which are multiplexed prior to being superimposed on the carrier, or a single information signal can be placed on the carrier. This would be called a single channel per carrier (SCPC) system, which has been widely used in satellite technology. Years ago, the analog information was superimposed on the carriers using Frequency Modulation (FM). More recently, the analog signals have been converted to digital pulse streams and the PSK and QAM techniques employed.

However, the FDMA wireless or satellite network offers a much less adaptive structure than TDMA regarding ease of reconfiguration for changing traffic demands. In Figure 1 (Right) is depicted the signal structure of the TDMA network, consisting of many traffic stations or users slots. In the FDMA method, guard bands are used between the adjacent signal spectra to minimize crosstalk between the channels. A specific frequency band is given to one person, and it will be received by identifying each of the frequency on the receiving end. It is often used in the first generation of analog mobile phone. The total time period that includes all traffic station bursts and network information is called the FDMA frame. Namely, the FDMA mobile devices are using available bandwidth into a given number of orthogonal channels of smaller bandwidths. A channel is used by users continuously over the duration of the message, and so the FDMA scheme is limited to narrowband applications due to its limited transmission rate. In such a way, if the same channel is reused at another physically separate location, an increase in transmit power will negatively affect the carrier-to-interference ratio at that location.

Therefore, in FDMA, each user is permanently allocated a certain frequency band, out of the total bandwidth of the transponder. To reduce the adjacent channel interference, it is necessary to have guard bands between the sub-bands. Frequency drifts of the satellite's and mobile earth station's frequency converters have also to be taken into consideration. The FDMA scheme is the traditional technique due to its simple implementation and FDMA allocates a single satellite channel to one user at once. In fact, if the transmission path deteriorates, the controller switches the system to another channel. Although technically simple to implement, FDMA is wasteful of bandwidth because the voice channel is assigned to a single conversation, whether or not somebody is speaking. Moreover, it cannot handle alternate forms of data, only voice transmissions. This system's advantages are that it is a simple technique using equipment proven over decades to be reliable and it will remain very commonly in use because of its simplicity and flexibility.

The FDMA technique has many advantages that can be summarized as the following:

1 A FDMA method is the relatively inflexible system and if there are changes in the required capacity, then the frequency plan has to change and thus, involve many GES terminals;
2 Multiple carriers cause IM in both the MES High Power amplifier (HPA) and in the transponder HPA. Reducing IM requires back off of the HPA power, so it cannot be exploited at full capacity;
3 As the number of carriers increases, the IM products between carriers also increase and more HPA backoff is needed to optimize the system. The throughput decreases relatively rapidly with the number of transmission carriers, therefore for 25 carriers it is about 40% less than with 1 carrier;

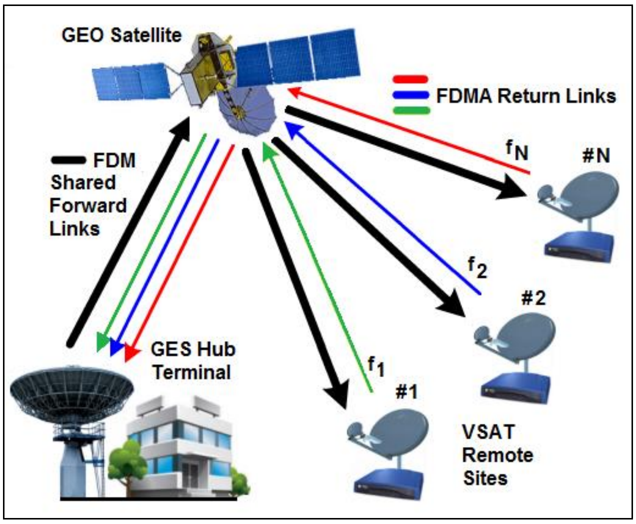

Figure 2. Satellite FDM/FDMA Network Architecture

4 The FM system can suffer from what is known as a capture effect, where if two received signals are very close in frequency but of different strengths, the stronger one tends to suppress the weaker ones. For this reason, the carrier power has to be controlled carefully;
5 The channel operations in FDMA are simple, FDMA technique doesn't need any base-control station, there is no need for network timing and no need for any equalization;
6 After the transmission of FDMA data, the effect of the delay distortion will be so small and it can be ignored, and data that is transferred between each station to another during the transmission process will not be lost; and
7 In FDMA, the reduction of the information bit rate has a good effect on the capacity, because of the transmission is continuous, there is almost no need for bits that are responsible for synchronization, and simplicity in FDMA algorithms.

The disadvantages of the FDMA technique are listed below:

1 The FDMA technique does not differ significantly from analog transmission systems; improving the capacity depends on the signal-to-interference reduction, or a Signal-to-Noise Ratio (SNR);
2 The maximum flow rate per channel is fixed and small and guard bands lead to a waste of capacity; and
3 Hardware implies narrowband filters, which cannot be realized in VLSI and therefore increases the cost.

Here can be concluded, that with the FDMA technique, the signals from the various users are amplified by the satellite transponder in a given allocated bandwidth at the same time but at different frequencies. Depending on the multiplexing and modulation techniques employed, several transmission hybrid schemes can be considered and in general may be divided into two categories, based on the traffic demands of Earth stations on MCPC and SCPC.

3 FREQUENCY DIVISION MULTIPLE ACCESS (FDMA) NETWORK CONCEPT

As outlined earlier, the FDMA technique is the earliest implemented in the wireless systems and still one of the most commonly employed forms of multiple access techniques for communications via satellite. In the case of FDMA different Earth stations are able to access the total available bandwidth of satellite transponder by virtue of their different carrier frequencies, thus avoiding interference among multiple signals. However, the FDMA technique is the first MAT technology implemented on fixed and mobile satellite systems. Its principle and operation are simple, which satellite FDM/FDMA network architecture is shown in Figure 2. Thus, the GES Hub terminal with shared forward FDM link is connecting 3 fixed or mobile VSAT stations via GEO satellite transponder. However, in return link, 3 VSAT stations are using separate FDMA links at a specific assigned frequency band (f1 , f2 , f N) is assigned to connect GES Hub terminal via the same via GEO satellite transponder.

Therefore, each VSAT station within the satellite's footprint transmits one or more signals at different carrier frequencies. Each carrier is assigned a small guard band to avoid the overlapping of adjacent carriers. The transponder receives all carrier frequencies within its bandwidth, does the necessary frequency translation and amplification, and then retransmits them back towards GES Hub terminals. Different VSAT stations are capable of selecting the carrier frequency containing messages of their interest. The frequency diagram determines that each VSAT station in communication via GEO satellite with GES Hub terminals monopolizes its own frequency band or frequency slot, which can be pre-allocated or changed as needed. As stated, a guard band is usually added between user bands to avoid mutual interference. The size of the guard band is related to the accuracy and stability of the carrier frequency of the transmitting and receiving ground station, and also to the difference of the maximum Doppler shift between adjacent signals. Therefore, the guard band set in the FDMA should be larger than any carrier signal. The maximum drift value relative to its nominal frequency for each station.

When the signal goes down, because the carrier spectrum passes through the frequency-converting satellite, the ground station needs to tune the receiver to a specific downlink frequency to receive the transmitting carrier of the corresponding uplink ground station. And because the entire FDMA spectrum is transmitted by each VSAT station on the return link to the GEO satellite. Than from GEO satellite on the downlink, that is, multiple carriers exist at the same time for each VSAT station, the GES Hub receiving station must be able to receive the entire spectrum from and filter it to distinguish the carrier actually sent to the station, and send it to other VSAT stations. According to whether each ground station uses multiplexing technology in the transmission carrier, FDMA is divided into two categories: FDMA (Multiple Channels Per Carrier-Frequency Division Multiple Access, MCPC-FDMA) and single channel per carrier. FDMA (Single Channel Per Carrier-Frequency Division Multiple Access, SCPC-FDMA).

3.1 *Multiple Channels Per Carrier (MCPC)*

The main elements of the MCPC are multiplexer, modulator, and transmitter using a satellite uplink (forward) when GES multiplexes baseband data is received from a terrestrial network and destined for various MES. Moreover, the multiplexed data are modulated and transmitted to the allocated frequency segment, when the bandwidth of the transponder is shared among several MES terminals, each with different traffic requirements. The transponder bandwidth is divided into several fixed segments, with the several time frequency divisions allocated to these MES terminals. Namely, between each band segment is a guard band, which reduces the bandwidth utilization efficiency and the loss is directly related to the number of accessing MES terminals in the network. Depending on the number of receiving MES terminals, a total number of carriers will pass through the satellite transponder.

On the other hand, the signals received from different MES terminal extract the carrier containing traffic addressed to LES by using an appropriate RF filter, demodulator, baseband filter and demultiplexer. The output of the demodulator consists of multiplexed telephone channels for a few MES terminals together with the channels addressed to them. A baseband filter is used to filter out the desired baseband frequency segment and finally, a demultiplexer retrieves individual telephone channels and feeds them into the terrestrial network for onward transmission. Each baseband filter of GES receive stations in this scheme corresponds to a specific one in the GES transmitting station. However, any change in channel capacity requires the return of this filter, which is difficult to implement, while many schemes may be categorized according to the type of baseband signal.

3.2 *Single Channel Per Carrier (SCPC)*

For certain applications, such as the provision of MES terminals to remote areas or individual MES terminal, traffic requirements are low. In reality, assigning multiple channels to each MES is wasteful of bandwidth because most channels remain unutilized for a significant part of the day. For this type of application, the SCPC type of FDMA is used. In the SCPC system, each carrier is modulated by only one voice or by low to medium bit rate data channel. Some old analog systems use Companded FM but most new systems are digital Phase-Shift Keying (PSK) modulated.

In the SCPC scheme, each MES carrier transmits a single carrier. The assignment of transponder channels to each MES terminal may be fixed Pre-Assigned Multiple Access (PAMA) or variable Demand-Assigned Multiple Access (DAMA), the channel slots of the transponder are assigned to different MES terminals according to their instantaneous needs. In the case of PAMA, a few SCPC channels, about 5 to 10, are permanently assigned to each MES terminal. In the case of DAMA, a pool of frequency is shared by many MES terminals. When necessary, each MES terminal requests a channel from frequency management of the Network Control Station (NCS), which may always attempt to choose the best available channel or a lower quality channel until an unoccupied channel has been found. The allocation is then announced on a signaling channel known as a broadcast channel. The announcement is received by the calling and called MES terminal, which then tunes to the allocated channel.

The communication takes place on the allocated satellite channel and the end of the call is announced by a signaling message, following which the NCS returns the channel to the common pool. In addition, the SCPS solution requires an Automatic Frequency Control (AFC) pilot to maintain the spectrum centering on a channel-by-channel basis. This is usually achieved by transmitting a pilot tone in the centre of the transponder bandwidth. It is transmitted by designated reference GES and all the MES terminals use this reference to correct their transmission frequency. A receiving station uses the pilot tone to produce a local AFC system which is able to control the frequency of the individual carriers by controlling the frequency of the LO. Drift in MSC translation frequency and frequency variations caused by the Doppler Effect and the carriers retain their designated frequencies relative to each other.

This feature is essential because if uncorrected, the sum of the total frequency error can cause carrier overlapping, as carrier bandwidths are small. Thus, a stable receive frequency permits the GES demodulator design to be simplified. Centrally controlled networks, such as Inmarsat MES standards of B, C, M, Fleet 33/55/77, FleetBroadband, and other GMSC networks are simple to manage missions because they provide a higher usage of channels and can use simple demand-assignment equipment. The SCPS scheme is cost-effective for networks consisting in a significant number of Earth stations, each needing to be equipped with a small number of channels.

The SCPC modulation systems previously contained a 64 Kb/s Pulse-Code Modulation (PCM) voice or data channel, superimposed on a carrier by 4-PSK modulation, using a transponder bandwidth of about 38 kHz. With a carrier spacing of about 45 kHz, a 36 MHz transponder could therefore carry about 800 channels of traffic. The dramatic improvement in digital compression techniques is reducing the voice channel bit rate down to 1 Kb/s or so. The minimum subjective quality level is the main point of discussion these days. Even at a voice bit rate of 16 Kb/s, which is relatively high by today's capability, this equates to 3200 channels per transponder. This figure can be improved by more than a factor of 2 by carrier voice activation. During the gaps in speech, a carrier is not transmitted, making space in the transponder for another carrier that has been voice-activated.

4 HYBRID FDMA NETWORK ARCHITECTURE

Further enhancement can be obtained when FDMA technique grouping is considered in combinations with TDMA, CDMA, and SDMA schemes in order to improve switching, transmission, and frequency bands conditions of baseband signals, and improve control of the satellite up and downlinks. There are several hybrid schemes of multiplexed FDMA in combination with FDMA/MCPC, FDMA/SCPC, FDMA/TDMA, SCPC/FM/FDMA, SCPC/PSK/FDMA, TDM/FDMA, TDMA/FDMA, TDM/SCPC, and TDM/SCPC.techniques.

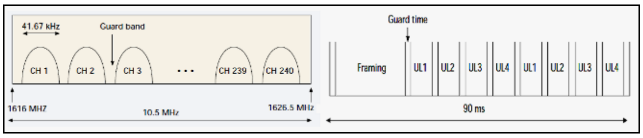

Figure 4. Iridium FDMA Scheme and TDMA Frame Structure

4.1 *Hybrid FDMA/MCPC Network Architecture*

The MCPC technique, as its name implies, is another FDMA technique in which each carrier contains several channels. Again, star networks with thin routes find MCPC to be a good alternative in some situations. Voice, data, or fax channels are time-multiplexed into one or several preassigned signals and then sent via a modem for transmission. Using speech coding to allow 16 Kb/s for each voice call, four calls can be multiplexed into a 64 Kb/s signal for one carrier. Data channels must be preassigned because speech encoders cannot be used with data traffic.

Usually, data is sent at 1.2, 4.9, 9.6, 56, or 64 Kb/s, and several different-rate users can be multiplexed for one carrier. Carrier preassignment is more suitable for star or point-to-point applications where a few VSAT stations use up to only six channels. A VSAT network would evolve as traffic increases, often beginning with a star network using MCPC to an SCPC/PAMA and eventually to an SCPC/DAMA. Further upgrades to a thin-route mesh network could follow. A TDMAstar configuration would be a major upgrade that would be cost-effective only with more than 25 remote stations each allocated at least 15 voice circuits.

4.2 *Hybrid FDMA/SCPC Network Architecture*

This access method does not require any multiplexing that is used for point-to-point, point-to-multipoint, and mesh networks. It is the VSAT equivalent of the conventional leased line, delivering up to about 2 Mb/s of bandwidth to individual VSAT terminals. Satellite channels are either preassigned (PAMA) or demand assigned (DAMA) mode. The SCPC/PAMA scheme dedicates channels to specific VSAT stations regardless of the network call activity.

The SCPC/DAMA hybrid systems are simple and cost-effective for small networks with less than four or five sites and several channels per site. The DAMA is a more efficient way of using the limited frequency resource. In SCPC/DAMA systems, users from different earth stations share a common pool of channels. For each call a request is sent and if a channel is available, it is assigned on demand. The DAMA system is more complex and the VSAT station equipment is more expensive, but the recurring space segment costs are lower. This is a type of concentrator mechanism, and traffic requirements need to be carefully studied; otherwise blocking can reduce the system effectiveness.

The DAMA system is suitable for many remotes when only a few channels are required for each remote VSAT station. If the traffic is too light, the additional cost of the DAMA control equipment negates the reduction in satellite charges. The GES Hub station controls the DAMA system by a common Aloha signaling channel. Moreover, the Aloha multiplexing system allows random contention (first come, first served) until the traffic becomes relatively heavy, at which time it changes to a reservation mode. The SCPC VSAT satellite networks are well suited to thin-route, rural telephony, and can even be the primary communication method for some developing countries. The SCPC system can accommodate voice or data traffic, whereas TDMA is best suited to data. Because SCPC is in direct competition with leased lines, it is not surprising that costs are similar, whereas TDMA services are comparatively cheaper.

4.3 *Hybrid FDMA/TDMA Network Architecture*

The Iridium GMSC system employs a hybrid FDMA/TDMA access scheme, which is achieved by dividing the available 10.5 MHz bandwidth into 150 channels introduced into the FDMA components. Each channel accommodates a TDMA frame comprising eight-time slots, four for transmission, and four for the sgnal reception. Each slot lasts about 11.25 msec, during which time data are transmitted in a 50 Kb/s burst. Thus, each frame lasts 90 msec and a satellite is able to support 840 channels. In such a way, a mobile satellite user is allocated a channel occupied for a short period of time, during which transmissions occur. The Iridium satellite system supports full-duplex voice channels at 4800 b/s (2400 b/s according to and half-duplex data channels at 2400 b/s. The IRIDIUM network utilizes multiple spot beams on each satellite that divide the satellite footprint into smaller cells. However, to provide two-way satellite communications, the IRIDIUM system uses a combination of Frequency Division Multiple Access (FDMA) and Time Division Multiple Access (TDMA) techniques.

The Hybrid FDMA/TDMA Network Architecture is established when two slots (same position in time) of the user are allocated in two different narrow-band radio channels. Iridium satellite system uses frequencies in the L-band of 1616 MHz to 1626.5 MHz for the user’s uplink and downlink with the satellites. This gives the system 10.5 MHz of bandwidth. As shown in Figure 4 (Left), the Iridium FDMA scheme divides the available bandwidth into 240 channels of 41.67 kHz for a total of 10 MHz. This leaves 500 kHz of bandwidth for guard bands, which amounts to approximately 2 kHz of guard band between channels. The TDMA frame is 90 ms long and it contains four full-duplex user satellite channels at a burst data rate of 50 kb/s. The four full-duplex channels consist of four uplink time slots and four downlink time slots, as depicted in Figure 4 (Right).

The eight user time slots take up a total of 69.12 ms, which leaves 20.88 ms of the TDMA frame for framing bits and guard time slots. A possible frame structure is to use a framing time slot twice as long as an individual user time slot. This would result in 864 framing bits taking up 17.28 ms. Subtracting this value from the 20.88 ms remaining in the TDMA frame leaves 3.6 ms for guard time slots. This can be divided into eight 400 microsecond guard time slots between time slots in the frame, and two 200 microsecond guard time slots at each end of the frame. Although the exact frame structure is not published in the open literature, this approach is reasonable. Thus, it uses 4.6 percent of the 90 ms frame for guard timeand utilizes 76.8 percent of the frame for actual data bits.

4.4 *Hybrid SCPC/FM/FDMA Network Architecture*

The baseband signals from the satellite network or users each modulate a carrier directly, in either analog or digital form according to the nature of the SCPC signal in question. Therefore, each carrier accesses the satellite on its particular frequency at the same time as other carriers on the different frequencies from the same or other station terminals. Information routing is thus, performed according to the principle of one carrier per link.

The Inmarsat-A MES standard used SCPS, utilizing analog transmission with FM for telephone channels. Thus, in calculating the channel capacity of the SCPC/FM system it is necessary to ensure that the noise level does not exceed specified defined values. Therefore, the International Radio Consultative Committee (CCIR) Recommendations for an analog channel state that the noise power at a point of zero, the relative level should not exceed 10,000 WOP with a 50 dB test tone, namely the noise ratio. In this way, it is assumed that the minimum required carrier-to-noise ratio per channel is at least 10 dB.

4.5 *Hybrid SCPC/PSK/FDMA Network Architecture*

In this hybrid scheme, each voice or data channel is modulated onto its own RF carrier. The only multiplexing occurs in the transponder bandwidth, where frequency division produces individual channels within the bandwidth. Various types of this multiplex scheme are used in channels of the Inmarsat standard-B system. In this case, the satellite transponder carrier frequencies may be PAMA or DAMA. For PAMA carriers the RF is assigned to a channel unit and the PSK modem requires a fixed-frequency Local Oscillator (LO) input. For DAMA, the channels may be connected according to the availability of particular carrier frequencies within the transponder RF bandwidth. For this arrangement, the SCPC channel frequency requirement is produced by a frequency synthesizer.

The forward satellite link assigned by the TDM scheme in shore-to-ship direction uses the SCPC/DA/FDMA solution for Inmarsat standard-B voice/data transmission. This hybrid standard in the return link for channel request employs the Aloha O-QPSK multiplexing scheme and for-low speed data/telex uses the TDMA scheme in ship-to-shore direction. The Inmarsat-Aero standard in forward ground-to-aircraft direction uses packet mode TDM scheme for network broadcasting, signaling dat,a and the circuit mode of SCPS/DA/FDMA scheme with distribution channel management for service communication links. Thus, the request for channel assignment, signaling and data in the return aircraft-to-ground direction the Slotted Aloha Binary Phase Shift Keying (BPSK) (1/2 – FES) of 600 b/s is employed and consequently, the TDMA scheme is reserved for data messages.

4.6 *Hybrid TDM/FDMA Network Architecture*

This arrangement allows the use of TDM groups to be assembled at the satellite in FDMA, while the PSK is used as a modulation process at the Earth station. Systems such as this are compatible with FDM/FDMA carriers sharing the same transponders and the terminal requirements are simple and easily incorporated.

The Inmarsat standard-B system for telex low-speed data uses this scheme in the shore-to-ship direction only and in the ship-to-shore direction uses TDMA/FDMA. The CES TDM and SES TDMA carrier frequencies are pre-allocated by Inmarsat. Each CES is allocated at least one forward CES TDM carrier frequency and a return SES TDMA frequency. So, additional allocations can be made depending on the traffic requirements.

The channel unit associated with the CES TDM channel for transmission consists of a multiplexer, different encoder, frame transmission synchronizer, and modulator. So at the SES, the receive path of the channel has the corresponding functions to the transmitted end. The CES TDM channels use BPSK with differential coding, which is used for phase ambiguity resolution at the receiving end.

4.7 *Hybrid TDMA/FDMA Network Architecture*

As previously stated, however, the TDMA signals could occupy the complete transponder bandwidth. In fact, a better variation of this is where the TDMA signals are transmitted as a sub-band of transponder bandwidth, the remainder of which being available for example for SCPC/FDMA signals. Thus, the use of a narrowband TDMA arrangement is well suited for a system requiring only a few channels and has all advantages of satellite digital transmission but can suffer from intermodulation with the adjacent FDMA satellite channels.

Accordingly, the practical example of this multiple schemes is the Tlx (Telex) service of the Inmarsat Standard-B system in ship-to-shore direction, which, depending on the transmission traffic, offers a flexible allocation of capacity for satellite communication and signaling slots.

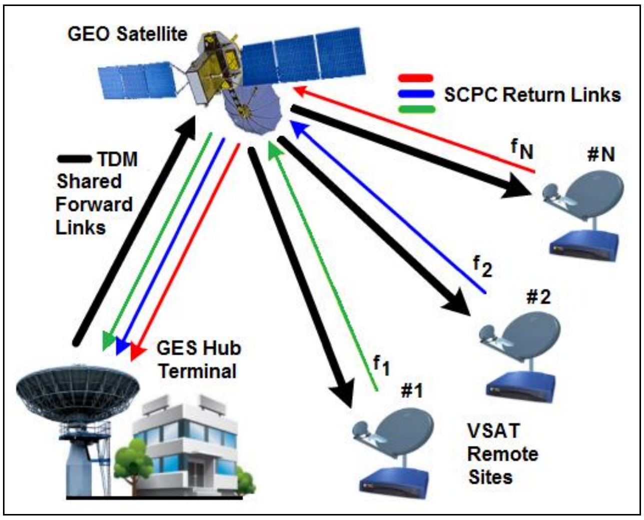

Figure 3. Hybrid TDM/SCPC Network Architecture

4.8 *Hybrid TDM/SCPC Network Architecture*

The TDM/TDMA and Single Channel Per Carrier (SCPC) architectures are the main alternative technologies for satellite networking in the world today. The modem and management technologies underlying both approaches have been advancing rapidly in recent years, causing some confusion as to which technology is better for a given set of networking requirements. The SCPC network refers to using a single signal at a given frequency and bandwidth. Most often, this is used on broadcast satellites to indicate that radio stations are not multiplexed as subcarriers onto a single video carrier, but instead independently share a transponder.

The SCPC mode is using for a VSAT satellite transmission system that uses a separate frequency carries for each of its communication channels, as opposed to frequency division multiplexing that combines many channels on a single carrier. It can be used for broadcast data and full-duplex audio and video communications. In an SCPC system, transmissions are sent to the satellite continuously on a single satellite carrier. The satellite signal is received at a single location, in the case of a point-to-point system, or at many different locations in a broadcast system, providing hubless connectivity among multiple sites. This technology a system where each sub-division carries only one 4-kHz voice channel enables companies and corporate organizations to establish their own private network to connect sites into a single network with highly reliable performance with very low latency.

Due to the increasing dominance of IP traffic, many former SCPC networks have already been converted to TDM/TDMA network architecture. However, some SCPC networks have converted only "half-way", whereby a DVB-S2 TDM carrier is used on the forward link, but SCPC links are used for return link communications. This hybrid configuration is called TDM/SCPC scheme and its network architecture is illustrated in Figure 3. If using DVB-S2 it gets the full benefits of statistical multiplexing and ACM on the forward link, but these benefits are non-existent on the return link in this hybrid network. Therefore, the technical and business rationales for using the TDM/SCPC hybrid networks are weak at best.

These possibilities or some of them are true with respect to the limitations of some popular TDM/TDMA technologies. For those technologies, the hybrid TDM/SCPC option is useful and may even be "cost-effective" in networks with nearly constant levels of traffic in the peak hour at each site, a consistent peak hour time each day. In Table 2 are presented the advantages and disadvantages characteristics of the TDM/SCPC technology with the cost of remote (VSAT).

Table 2. List of TDM/SCPC Characteristics

Advantage	Disadvantage
Dedicated bandwidth for each remote inbound	Each remote requires its own space segment
Provides superior Quality of Service for mission critical applications	Expensive OPEX if each remote bandwidth is not fully utilized
Low Latency and Low Jitter	SCPC modems typically more expensive than TDMA modems
Best transmission method for real-time applications, voice, data, video, broadcast, etc.	Fixed data rates on the inbound links

Nonetheless, the TDM/SCPC hybrid configuration is commonly promoted and used in certain types of VSAT networks, in particular in cellular backhaul networks and in some other types of networks where fast access to large amounts of capacity for the return link (upstream) traffic must be guaranteed. There are four possible reasons for the continued use of this form of SCPC confirguration:

1 The possibility that SCPC in "continuous mode" will provide better modem efficiency (in b/s per Hz) than TDMA burst mode due to lower overhead and ability to use higher-rate, more efficient MODCOD scheme;
2 The possibility that SCPC links are better at providing guaranteed capacity and will operate more reliably against rain fades, interference, or congestion;
3 The possibility that SCPC links will provide lower latency or less total delay; and
4 The pssibility that SCPC links can be operated at a higher speed, when necessary, for any or all sites within the satellite transponder footprint.

However, in comparison to satellite TDM/TDMA networks using the DVB-RCS2 standards, these conditions do not hold true. In fact, the opposite is true, because, in terms of total network efficiency, a satellite DVB-RCS2 return link operating in TDMA burst mode will deliver 2x more in bps/Hz than some popular SCPC options, even before adding in the benefits of statistical multiplexing with TDMA configuration.

4.9 *Hybrid SDMA/FDMA Network Architecture*

This modulation arrangement uses filters and fixed links within the satellite transceiver to route an incoming uplink frequency to a particular downlink transmission antenna. A basic arrangement of fixed links may be set up using a switch that is selected only occasionally. Thus, an alternative solution allows the filter to be switched using a switch matrix, which is controlled by a command link. Because of the term SS (Switching Satellite), this scheme would be classified as SDMA/SS/FDMA. The satellite switches are changed only rarely, only when it is desired to reconfigure the satellite, to take account of possible traffic changes. The main disadvantage of this solution is the need for filters, which increase the mass of the payload.

5 CONCLUSION

In this paper are provided the following conclusions: FDMA technique is widely used in the analog telecommunication systems. The working principle of the FDMA as we said is dividing the signaling dimensions along the frequency axes to create many separate channels and allocate these channels to users. The guard bands have an important effect on decreasing the transmission impairments. Despite the advantages, FDMA has many disadvantages such as constant data rate and capacity and is used in many applications such as analog mobiles and satellites. Then, allocating a single frequency channel for short time and then moving to another channel to give it its own interval.

The performances and capacities of GMSC for CDMA, FDMA, and TDMA/FDMA have been analyzed many years ago for an L/C-band network with global coverage. For the particular MSS under discussion and for the particular antenna configurations, both CDMA and FDMA offer similar performance, FDMA yielding slightly higher channel capacities at the design point and CDMA being slightly better at higher Equivalent, Isotropically Radiated Power (EIRP) levels.

The communication satellites for MSC provide multiple-beam antennas and employ frequency reuse of the allocated L-band frequency spectrum. It appears that despite the fact that FDMA and FDMA/TDMA are orthogonal systems, they nevertheless suffer from bandwidth limitations and sensitivity to interbeam interference in L-band. However, at the chosen design point for aggregate EIRP, a number of beams, and allocated bandwidth, FDMA provides still the highest system channel capacity.

REFERENCES

[1] Popoola S.I., (2016), "Mobile & Personal Communications", Department of Electrical and Information Engineering, Covenant University, Ota, Nigeria, 34.
[2] Richharia M., (2020), "Satellite Communication Systems", Springer, Boston, 484.
[3] Ilcev, (2017), "Global Mobile Satellite Communications for Maritime, Land and Aeronautical Applications - Volume2", Springer, Boston, US, 686.
[4] Ivanov A., at all, (2019) Physical Layer Representation in LEO Satellite with a Hybrid Multi-Beamforming,

Skolkovo Institute of Science and Technology, Moscow, 7.
[5] Ilcev D. S. (2011), “Global Mobile CNS”, Manual, CNS Systems, Durban, South Africa, 285.
[6] Maini A.K. & Agrawal V., (2007), “Satellite Technology - Principles and Applications”, John Wiley, Chichester, 696.
[7] Garvey G., (2013), "Multiple Access Techniques", Atlanta RF, LLC, Roswell, GA, 53.
[8] Xu X., at all, (2018), "Combination of Asymmetric PCMA and Common Multiple Access Technology", Army Engineering University of PLA, Nanjing, China, 9.
[9] Pratt S.R. at all, (1999), "Operational and Performance Overview of the Iridium Low Earth Orbit Satellite System", IEEE Communications Surveys, New York, 9.
[10] Al Hares M.K, at al, (2008), "DMA & FDMA Techniques", University of Kent, Canterbury, Kent, UK, 26.
[11] Robert G. Winch R.G., (1993), "Telecommunication Transmission Systems", McGraw-Hill, New York, 633.
[12] Popoola S.I., at all, (2016), "Multiple Access Techniques: Design Issues in FDMA/TDMA", Manchester Metropolitan University, Manchester, UK, 34.
[13] Gigard R, (2020), "Satellite Network Design", Intelsat, McLean, VA, 53.
[14] Gagliardi R.M., (1991), “Satellite Communications”, Van Nostrand Reinhold, New York, 592.
[15] Ohmory S., Wakana. H & Kawase S. (1998), “Mobile Satellite Communications”, Artech House, Boston, 466.
[16] Telecomunicazioni, (2008), "TDMA, FDMA, and CDMA" University of Rome La Sapienza, Rome, Italy, 42.
[17] Kim H.W., at all, (2012), Applicability of Orthogonal Frequency Division Multiple Access in Satellite Communication", ETRI, Daejon, South Korea, 6.
[18] Sheriff R.E. & Hu Y.F., (2001), “Mobile satellite communication networks”, John Wiley, Chichester, 381.