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A Study on the Hybrid System of MF-TDMA + SCPC Application to Ship Satellite Systems

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Abstract

All ships make good use of the satellite transportation system to communicate external as well as internal data understanding on the sea. At that time, there is diverse kinds of information to communicate one another such as voice, letter, picture and video on the sea to sea, sea to ground. In addition, there are other means to share information like a sign, voice, message, picture and video shared between vessels and ground units. Although the ships utilized FDMA in the initial stage of the satellite procurement, MF/TDMA method is recently applied as means to transmit information. Both FDMA and MF/TDMA, however, are not the best means of data transmission as the number of bandwidth is limited for both methods. Thus, in order to provide a solution for this problem and to see how the amount of transmission increases, a research on applying MF-TDMA + SCPC has been conducted for the Navy's satellite communication system for the efficiency of the satellite network within the original frequency bandwidth will be maximized through the application of digital transformation methods and Roll OFF Factor as a means of data transmission.

***Keywords**: Satellite communications, multi-frequency time division multiple access, the network, reliability, scalability*

1. Introduction

Ships on the sea utilize a satellite transportation system as a means to communicate with other ships of the ground and the sea. Most of the ships on the broad sea resort to satellite transportation to share large amount information by using limited frequency. Indeed, tremendous amount of multi-media information is increasing thanks to remarkable scientific progress. Furthermore, it is critical to keep reliability in that one has to share with necessary information continuously in urgent occasions. As seen in the case of the SEWOL ship, it is necessary to keep reliable satellite communication to be in commune with one another in disastrous accidents for a long time within frequency bandwidth lengths.

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2. Related Research

2.1. Roll-Off Factor

When it comes to the assigned frequency bandwidth for the transmission of data information, the real applicable bandwidth is called procurement bandwidth length. With maximizing bandwidth, it is possible to increase the amount of transmission. However, it is necessary to beef up the output of reception conditions so as to strengthen the procurement bandwidth length for the sake of more than requirement value of reception signal level. The Roll-Off Factor (herein referred to as RoF) of digital filter is the definition value of the procurement of bandwidth. It is possible to improve the reliability and transmission amount of satellite communication to optimize RoF. As a usual, the standard of DVB-S2 requires 20%, 25%, 35% Roll-Off Factor. Furthermore, with the progress of communication, it is common to diminish Roll-Off Factor even up to 5% [1].

2.2. Digital Modulation

When it comes to transmissible second rank data, it is available to transmit two data in a beat or several beats in one symbol. Based on the information that a symbol keeps, it transforms the characteristic of a carrier signal, which is called a digital modulation system.

This digital modulation system varies the amplitude of a carrier signal. Plus, it can be divided into several levels based on its symbols such as Amplitude Shift keying (herein referred to as ASK), Frequency Shift keying (herein referred to as FSK), and Phase Shift keying (herein referred to as PSK). In addition, there are several methods such as QAM(Quadrature Amplitude Modulation (herein referred to as QAM) which is combined ASK with PSK, Differential Phase Shift keying (herein referred to as DPSK), QPSK(Quadrature Phase Shift keying (herein referred to as QPSK) and others [2].

2.2. Digital Modulation

FDMA. The FDMA is a method continually using a channel in a frequency band without any time limit by dividing the frequency band width and using them [3]. As representative FDMA methods, there is a SCPC method which is suitable for a satellite communication network with low traffic and numerous earth stations, and the MCPC (Multiple Channel per Carrier) transmitting many channels with only one carrier wave.

MF-TDMA. MF-TDMA is a method enabling several earth stations to share one satellite repeater by inserting the same frequency into each different time zone being assigned to each earth station in order to avoid overlapping several earth stations' frequencies on the satellite repeater [4]. This transmission method has disadvantages and it needs to be synchronized to avoid any interference during complex signal processing. [5].

MF-TDMA + SCPC. MF-TDMA + SCPC hybrid method assigning channels to multi-operators by applying the SCPC to the MF-TDMA enables it to support a network structure where terminals having various frequency bandwidth lengths are mixed by using the resource assignment technique. The method of MF-TDMA+SCPC can set a specific frequency hopping pattern and operate it, keeps its efficiency for resource assignment even in a network where terminals with having various frequency bandwidth's lengths are mixed by applying the primarily assigned time technique based on a mission's characteristic or data type and the method assigning frequencies at the same time. In addition, it secures the reliability of data transmission with more continual data transmission as well as responding against the consecutive jamming of control channel and finally improve the transmission speed and increase the traffic [6]-[9].

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3. Application of Transmission Method of MF-TDMA + SCPC

3.1. Comparison Circuit and Reliability with Transmission Amount

One should take ship satellite communication on the sea into account reliable transmission and the guarantee of maximized reliable transmission amount within frequency bandwidth lengths. In this study, I have analyzed the amount of transmission in connection with the reliable circuit and application of FDMA, MF-TDMA and MF-TDMA + SCPC.

The entire symbol amount of a group is based on Link Budget through the application of 8PSK modulation system in all bidirectional ways and 5/6 FEC which set the value of RoF as 1.2. When it comes to TDMA, considering the significance of the obligation of transmission rate, it applied 50% on its condition with the goal of 1Mbps per tow circuits and bandwidth lengths are as under.

▪ TDMA(8PSK, 5/6 RFEC, RoF : 1.2 application, bidirectional communication) Frequency

Σ = {[(1Mbps : downward look) x 5 circuit+(1Mbps x 5 circuit x 50% : inbound)] x (1÷3) x (6÷5)} x 1.015(O.H) x 1.2(RoF) = 3.654MHz, Simply put, about 3.7MHz frequency bandwidth is required.

▪ FDMA(8PSK, 5/6 RFEC, RoF: 1.2 application, bidirectional communication) Frequency

Σ = [(1Mbps x 5 circuit) x (1÷3)(8PSK) x (6÷5)(1/FEC) x 1.015(O.H) x 1.2(RoF)] x 2(bidirectional) = 4.871MHz, Simply put, about 4.9MHz bandwidth length is required.

As seen in the above calculation, the efficiency of frequency bandwidth lengths can lead to the 32.4% efficiency in TDMA method. This efficiency of frequency can be more improved in an advanced technology rather than that of TDMA or FDMA. More specifically, it has relatively lower filtering demand Eb/No value (C/N Ratio) than superior filtering function. That's why, when it comes to Outbound, it can perform the survival of higher transmission rate by applying bidirectional ACM (Adoptive Code & Mod) function Rain Fading or by applying lower value of 7/8, 8/9 and others under the equal condition of FEC quality by lowering the RoF value to 1.05 values.

However, as long as the public user bandwidth in TDMA is concerned, there are diverse transmitting traffics including business data, images, and voices demanded in each terminal. Furthermore, the priority of selecting method in each traffic should be carefully dealt with based on packets, terminals, destinations, ports and others.

Subsequently, FDMA is superior not only in speed and damage of jamming but in security and reliability based on its users. TDMA has the bandwidth to manage frequency efficiency, jamming and its network. On the other hand, although it is excellent in security, it has weakness in its Outbound and operation.

Accordingly, one has to take security and reliability into account so that they can be applicable to design diversely by applying MF-TDMA+SCPC in terminals and equivalent Hub.

As demonstrated above, it is known that FDMA method and TDMA have their own unique strengths and weaknesses. Based on these examinations, when you actively operate these two ways well, you can overcome the shortcoming.

Currently, many communication businesses utilize this two-way system. However, they have strengths and weaknesses in that they individually operate it rather than they mutually manage it in one place based on existing technological foundation following user's purpose for a long time. In other words, with full-fledged size of FDMA facilities and individual passive circuit management including TDMA terminal control and well as

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operating individual network manager, excessive expenses for the large scale management of them and its complexity are invested.

However, if constructing TDM/MF-TDMA and SCPC channels which are available incorporating control in a single platform, it is possible to actively utilize strengths of each way and save excessive expenses in its operating facilities by circulating distribution of network system in a real time processing. Thus, this study attempts to investigate how to improve the network of satellite communication by using these system functions.

4. Hybrid System of MF-TDMA + SCPC

4.1. Roll-Off factor & Digital Modulation

Link Budget designs and calculates the profits of answerback, exponent of noise, and margin and various elements of sender as well as safe circuit quality. It is very important to calculate the optimized value of transmission. For this purpose, I have demonstrated various values of Roll off Factor and their results. When comparing 20% Roll-Off Factor value and 5% Roll-Off Factor value with Spectral, the latter shows similar figure of Brick-Wall filter and there was a 0.58dB difference of Power Spectral Density (PSD).

As a usual, ROF of satellite system applied to ships demands 1.25~1.3, equivalent to a 25~30% guard net. The current frequency bandwidth length is 20Mhz in average, and main modulation system uses QPSK. On the other hand, FEC code uses 5/6. Meanwhile, RoF value fundamentally uses equivalent ratio, applying 1.25 in average [10][11]. When it comes to the analysis of transmission amount based on this fact, it is as under.

Table 1. Transmission Rate of Current Roll-Off Factor System

Division	Analysis of current system of Modem RoF	
	Applying RoF	Data Rate
Outbound	1.25	26.2 Mbps
Inbound	1.25	26.2 Mbps
Note	Modulation System : QPSK, FEC 5/6 commonly applied	

※ Data Rate (Mbps) = 20MHz ÷ 1.25(RoF) × 2 (QPSK) × (5÷6)(FEC) ÷ 1.015 (Packet / Frame Overhead)

If the value of RoF changes from 1.25 to another level, the efficiency will be on the rise. When applying the procurement frequency bandwidth length, modulation system, and FEC Code to equal condition and different value of Inbound /Outbound value, such as applying the Inbound to 1.05 and Outbound to 1.2. As a result, the transmission amount comes out as under.

Table 2. Transmission Rate of Improved Roll-Off Factor System

Division	Analysis of current system of Modem RoF		Note
	Applying RoF	Data Rate	
Outbound	1.05	26.2 Mbps	Current Comparison 5 Mbps increase
Inbound	1.2	26.2 Mbps	Current Comparison 1.1 Mbps increase
Note	Modulation System : QPSK, FEC 5/6 commonly applied		

When comparing the two preceding results mentioned applying RoF to Outbound 5% and Inbound 20%, the transmission increasing rate of Roll-Off-Factor shows as under. Meanwhile, when the improved Roll-Off-Factor is applied, it is possible to cut down the bandwidth width in a large scale.

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Table 3. Improved Transmission Increasing Rate of Roll-Off Factor

Division	Existing RoF application		Improved RoF application		Analysis increasing rate	
	Applying RoF	Data Rate	Applying RoF	Data Rate	Increasing Rate	Rate
Outbound	1.25	26.2Mbps	1.05	31.2Mbps	5Mbps	19%
Inbound	1.25	26.2Mbps	1.2	27.3Mbps	1.1Mbps	4%
Note	Modulation System : QPSK, FEC 5/6 commonly applied					

As a usual, the satellite system uses QPSK modulation system. When analyzing the transmission amount by comparing modulation system with 8PSK modulation system, the result shows as under.

Table 4. Analysis of Transmission Rate Based On Modulation System

Division	QPSK		SPSK		Analysis increasing rate	
	Modulation System	Data Rate	Modulation System	Data Rate	Increasing Rate	Rate
Outbound	QPSK	26.2Mbps	8PSK	39.4Mbps	13.2Mbps	50%
Inbound	QPSK	26.2Mbps	8PSK	39.4Mbps	13.2Mbps	50%
Note	Modulation System - RoF :1.25 - FEC Code : 5/6 commonly applied					

It proves that there was a difference in transmission increasing rate in the application of modulation system from QPSK to 8 PSK under equal conditions.

4.2. Appropriate Ratio According to the Operational Plan

As seen in 2.1.2, the efficiency of frequency gets about 69% and 54% out of TDMA network in Outbound and Inbound with the application of bidirectional 8 PSK through the lower system of Eb/No value as well as Roll-Off Factor value.

The operation for getting reliability of circuit is available based on its speed security type SCPC channel and Broadcasting type TDMA channel based on its purpose and circumstances of ships.

Central equipment is composed of appropriate ratio based on the operation plan of answerback TDMA and SCPC and performs the selection of circuit and change in terms of remote control following a operating instruction.

More specifically, when operating 100 movable ships and five fixed stations, including ocean tasks, ground standby, and repair group, more than two groups except for a repair group should maintain its operating condition as under. At this point, some of repairing groups or entire groups, under the condition of not allowing the permission of terminal modem or not a tracing condition, is subject to the access of automatic TDMA especially when moving to a searchable place to detect satellite because it becomes Logout in TDMA group.

As a usual, in the case of coast guard ships or ships, not all ships are operable at the same time due to the loading physical distribution and repairing. Accordingly, considering this point, I assumed the operable scenario by calculating 70% the operating rate as under Table 5.

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Table 5. Ship Operation Scenario on Duty (Operation Rate 70%)

Division		scenario 2 routine + disaster measure
Obligation (always)	Fixed Station(2 Mbps)	5
	A - type(2 Mbps)	9
	B - type(1 Mbps)	16
	C - type(0.5 Mbps)	9
	Sub Total	39
standby (always)	A - type(2 Mbps)	6
	B - type(1 Mbps)	8
	C - type(0.5 Mbps)	19
	Sub Total	33
repair (not available)	A - type(2 Mbps)	
	B - type(1 Mbps)	14
	C - type(0.5 Mbps)	19
	Sub Total	33
Total	Fixed Station + A-type	17
	B - type	41
	C - type	47
	Sub Total	105
Note	Sewol ship accident Additional assignment on the spot	

At this time, the frequency bandwidth length of TDMA gets 32.4% from an FDMA viewpoint, considers the strengths of TDMA and SCPC, applies comprehensive operating rate, and establishes TDMA + SCPC operating rate as under Table 6.

Table 6. Consider Factor on TDMA + SCPC Operating Rate Setting

Division	Rate	Consider Factor
TDMA	80 %	Operation rate 70% appropriate bandwidth length assigned
SCPC(FDMA)	20 %	Leading ship, countermeasure ship on the spot

Likewise, I assumed, when it comes to the Parameter value of satellite modem, that Outbound sets up QPSK, 5/6 FEC, and RoF 1.25. Whereas, Inbound established QPSK, 5/6 FEC, and RoF 1.25. Contention Ratio is generally assigned temporarily to see how many terminals per carrier are used, which applies 1:10~1:20. However, in this calculation, many demanded traffics are frequently demanded. As a result, fixed station is applied as 1:3, and ships were applied as 1.6. When it comes to the terminal of ships, 1/3 is assumed as a duty, 1/3 as standby, 1/3 as repair stage. The chief task of traffic is ships on duty; standby ships use fixed assigned bandwidth (128Kbps) to maintain online network in minimum. In case assuming automatic Logout, operating ships indeed were applied under the assumption of equal contention ratio such as 1:3 and 1:2.

By applying above contents, the number of ships on duty for volume transmission and FDMA (SCPC) ships is as followed Table 7 and the TDMA ships are as Table 8.

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Table 7. Leading Ship and SCPC Ships If Needed

Division	Obligation	Expected Ships	Demanded Bandwidth	Note
Fixed Station / Large Scale Ship	Leading / Relay	11	22Mbps	Preparing TDMA/ SCPC 32% Considering the efficiency of frequency, 20% SCPC operation is considered
Medium Size Ship	Local Countermeasure and Relay	11	11Mbps	

Table 8. TDMA Operating Ship

Division	Obligation	Expected Ships	Demanded Bandwidth	Note
Fixed Station / Large Scale Ship	Leading / Relay	6	4Mbps	Preparing SCPC, 32% frequency efficiency considered and TDMA 80% considered to operate
Medium Size Ship	Local Countermeasure and Relay	30	5Mbps	
Small Scale Ship	Leader's Local Countermeasure	47	4Mbps	

4.3. Compare the Frequency Band

Based on previous conditions, when calculating existing system criteria of bandwidth, like initial assumption of TDMA and SCPC, it was analyzed that 70% of operating rate needs 70.4Mhz of frequency to satisfy fixed station, A, B, C type transmission rate by using criteria of 80:20.

Table 9. Frequency Bandwidth Length Analysis of Existing System

Circuit	Station Number										Station Subtotal	Carrier Number	Frequency Bandwidth Length
		Operation			Standby			Repair					
	Fixed Station	Leading Type	Medium	Small	Large	Medium	Small	Large	Medium	Small			
TDM Outbound											1	1	9.9
SCPC Out (2M)											11	11	16.8
SCPC Out (1M)											11	11	8.4
Outbound Subtotal											1	23	35.1
Fixed Station & A – Type (TDMA 2 Mbps)	5	1									6	2	3.1
B – Type (TDMA 1			3	2		5	6	1	7	6	30	5	3.9

Mbps)													
C – Type (TDMA 0.5 Mbps)			3	6		3	16		2	17	47	8	3.1
A – Type (SCPC 2 Mbps)		3	3	2	1	2					11	11	16.8
B – Type (SCPC 1 Mbps)		2	4	5							11	11	8.4
Terminal Subtotal	5	6	13	15	1	10	22	1	9	23	106	37	35.3
Terminal Total		34			33			33					
Bidirectional Total												60	70.4

I have analyzed necessary frequency based on the amount of transmission by applying new technological modulation system (QPSK→8PSK) in contrast existing system of Roll of Factor(Outbound 1.05, Inbound 1.2). TDMA and SCPC were based on 80:20 as a current criterion. As a result, it demonstrated 70% working rate and fixed station, A, B, C type transmission rate, RoF and modulation system, and operating scenario. Plus, it showed 442.5 Khz as shown in Table 10.

Table 10. Frequency Bandwidth Length Analysis of New Technology Applied System

Circuit	**Station Number**										**Station Subtotal**	**Carrier Number**	**Frequency Bandwidth Length**
		Operation			Standby			Repair					
	Fixed Station	Leading Type	Medium	Small	Large	Medium	Small	Large	Medium	Small			
TDM Outbound	1										1	1	19.9
Outbound Subtotal											1	1	19.8
Fixed Station & A – Type (TDMA 2 Mbps)	5	1									6	2	2
B – Type (TDMA 1 Mbps)			3	2		5	6	1	7	6	30	5	2.5
C – Type (TDMA 0.5 Mbps)			3	6		3	16		2	17	47	8	2
A – Type (SCPC 2 Mbps)		3	3	2	1	2					11	11	10.8
B – Type (SCPC 1 Mbps)		2	4	5							11	11	5.4
Terminal Subtotal	5	6	13	15	1	10	22	1	9	23	106	37	22.7
Terminal Total		34			33			33					
Bidirectional Total												38	42.5

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As seen in Table 9 and Table 10, it has been analyzed that the efficiency of existing frequency versus newly applied technology system was reduced b 40% bandwidth lengths under the same condition of 70% operation rate. Simply put, it was possible to improve 40% transmission speed or to operate satellite modem for 45-45 ships based on the standard of five fixed stations and 100 ships. Comparing two deducted methods, it is as following Table 11.

Table 11. Comparing Frequency Bandwidth Length with Existing System VS New Technology Applied System

Division	Frequency bandwidth length (Mhz)			Efficiency
	Outbound	Inbound	Total	
Existing System	35.1	35.3	70.4	Current 40% bandwidth length reduced
New Technology Applied System	19.8	22.7	42.5	

5. Conclusion

As stated in the above, ships on the sea mainly utilize a network of communication. Many ships use limited satellite communication by applying initially FDMA and currently MF-TDMA. However, I have applied MF-TDMA+SCPC for the sake of maximized efficiency by applying these two ways. As a result, I could verify the possibility of improving data reliability and transmission amount by applying Roll OFF Factor amplifying procurement bandwidth lengths. Furthermore, I also found that transmission amount increases by applying digital modulation system as a means of transforming data in transmission. It is excellent in speed and reliability by applying the method of MF-TDMA+SCPC. In addition, it was possible for many ships to increase the transmission speed and amount by splitting time. In closing, it will be able to enhance the capability to take measure intentional jamming and network security by studying further in future.

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