Issues on Development of Communication Technology Using Orbiting Satellites

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Ministry of Defence, New Delhi 110 011

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Preface

This monograph is the result of more than 38 years of my experience to be involved with research and developments in the field of communication systems along with validation and facilitating production of the total systems, particularly to defence department. Additionally an experience of teaching at a very reputed institution, Indian School of Mines at Dhanbad and close association and interactions with the board of studies at Indian School of Mines at Dhanbad as well as Birla Institute of Technology, Mesra, Ranchi have helped me to understand - what the shortcomings in the teaching materials at academic institutions are and what the engineers face, when they are to design a complete communication systems for different uses and applications. Just for example let me take an example from the two basic devices forming the backbone of wireless transmission in digital technology, i.e., ADC and DAC, the Analog to Digital converter and Digital to Analog converter. The specs. of these two vital devices are entirely different for telecommunication and process instrumentation applications, which are generally neither mentioned in any text or reference book and nor explained in teaching institutions. As such no recommended text book ever mentions such issues, while concentrating on the application of mathematical techniques, primarily showing how algebraic techniques are applied in explaining the different theories. There are many such areas, which are never explained while teaching and thus engineers get somewhat puzzled while becoming part of any large system specifically meant for specific usage by specialised units, whether in defence or areas like commercial areas, e.g., mining and geophysical applications.

It is what appeared to demonstrate during field trialfor the digital troposcatter systems.

Thus the concept of system engineering which requires somewhat deep understanding from other engineering areas and behavioural aspects of

users need to be evolved while developing useful and successful systems as have been the MSS briefcase terminals, for which the author has been the leader for development along with a team of engineers from other disciplines and many other companies. Just for example, the communication techniques for static usagecan not be same as for airborne terminals for practical applications.

Coming back to the subject area of application of orbiting satellites as a next generation alternative to geosynchronous satellites in mobile telephony specially suited to defence forces and disaster mitigation teams, which involves defence forces, we find there are many issues in addition to the ones we face while using geosynchronous satellites. These are what have been explained in this monograph as have been the scenario in the early part of this decade since 2008-09. Needless to say that if this author is asked now to write a monograph to be undertaken now, based on the experience as he has got in my service period, it would be different somewhat, though the importance of the basic concepts used in this monograph shall remain and have to be incorporated. In the area of telecommunication, we have seen the transmission to OFDM from FDM, sampling beyond Nyquist rate, etc., and now these alongwith QAM techniques would find its applications!

It is here the author needs to mention the very valuable comments from one of the reviewers on this manuscript primarily, the story telling way, the monograph has been written and the reasons for unnecessary detailed explanations of the techniques to be used to take up the development activities in this defined areas. Let me now elaborate why such approach has been adopted from personal experience. This author has seen experienced engineers from other areas getting involved in areasoutside their experience. It needs refreshing of old knowledge, which may or may not have been learnt by the concerned engineer. This author faced the problem himself when he joined DEAL, Dehradun as a scientific officer in 1976 and had been in microwave division without any background of microwave but having background of electrical control techniques. The existing books in the area were too theoretical and the text books were not useful to provide him the necessary background in an easy manner. Further in BEL the development of mobile digital troposcatter communication had to be carried out, again for which requisite background of propagation aspects were not available to this author. Thus after retirement, when the author has been tasked to write this monograph, the approach needed to be in story telling mode and explaining each step, as necessary, to take up execution of the activities.

Under the backdrop of what has been mentioned, it is understood that this monograph is suitable for any engineer having a minimal background of telecommunication, to be able to understand and appreciate the issues in development of a mobile telephony using orbiting satellites, which are the next generation of satellite communications. This monograph will serve as a basic reference for understanding of the subject. Let us accept that further with the advent of LTE, a new type of UAV or drone is also possible for use as a base station in the sky for mobile connectivity. Newer developments are the order of the day.

It needs to be stressed that the author has only written a part of what his experience in wireless telecommunications with various colleagues, whether from users or development area. To be somewhat specific, the author places his highest regard and deepest gratitude to Dr UC Ray of SSPL, New-Delhi for encouragement ,motivation and guidance to write the monograph. In Bharat Electronics Ltd., the interesting technical discussions on radio, the author had with Mr DK Chatterjee of BEL, Ghaziabad, while development and support during extensive field trials of troposcatter radio systems and lively discussions with DEAL Scientists namely Dr CK Chatterjee, Dr BS Jassal, Mr Pinaki Sen, Mr LC Mangalas well as Mr Manoj Kumar of BEL Ghaziabad unit, and the team led by Mr LC Burman of CRL, Bangalore, while developing satellite communication systems, have helped the author in getting a basic understanding on practical problems and real life issues. The mentoring of Prof Dinesh Chandra of Indian School of Mines, Dhanbad while working under him for a period more than 4 years can never be ignored. Lastly, the experience shared by Mr SD Bawa (late) with personal support of Mr Ganesh Ramchandran of BEL Ghaziabad during early nineties, as well as support of Major S Bali of Indian Army to fabricate small circuits on sand paper (as a pre-cursor to flexible PCB) during field trials, have helped the author to conduct some interesting experiments in the field trial using digital troposcatterequipments. These have enriched the knowledge of this author and helped to incorporate in this area. The support of DESIDOC in finalising the manuscript has finally helped in translating some of these experience and knowledge into a printable format.

Finally it will be a satisfaction if the monograph finds some use towards the area it is meant for realisation of a very important type of satellite communication systems.

Acknowledgements

This monograph is a next-generational extension of the original satellite terminals, commonly known as MSS briefcase terminals in the decade 2001 to 2010. While working for development of MSS briefcase terminals, the commercial failure of IRIDIUM terminals using LEO satellites came to the notice of the author. Considering our expertise as developed in the development of the MSS terminals, and the experience of digital troposcatter systems in both developments and field trials, the natural thoughts for next generation of satellite terminals with complete geographical reach has come about.

The original encouragement for the development for satellite systems using LEO satellites was from Dr UC Ray of Solid State Physics Laboratory of DRDO. The encouragement from Dr CK Chatterjee of ex-DEAL and other team members, like Dr BS Jassal, MR LC Mangal, Mr Pinaki Sen from DEAL were invaluable, not only in getting the MSS briefcase terminals to an acceptable level, but also laying foundations for taking the activity of concept formation as next stage of mobile satellite terminals. From BEL side the efforts of Mr LC Burman, Mr Sivaram Prasad of CRL-BG and Mr Manoj Kumar, Mr Deepak Kumar and Mr Anuj Jain have been very vital and contributing important roles, to bring up the project in proper shape. Without active support of all of them, the project titled 'MSS briefcase terminals' would not have come up to an acceptable level.

Further, the author had been the key person for the development of digital mobile troposcatter communication systems from conceptual planning, practical development as well as getting approved by Indian Army through extensive field trials as well as facilitating production of the system. The activity of the troposcatter systems were spread from 1984 till the end of nineties, spread over approximately 15 years taking care of many versions

to suit airforce as well as army. It provided a vast experience of the issues of wireless communication systems, and the ways the issues needed to be resolved to the satisfaction of users. Certain issues for practical realisation of next generation of satellite terminals as mentioned in this monograph, were learnt in the long duration of the development and acceptance by users. In this connection the support from Major S Bali of Indian Army, Mr SD Bawa and Mr Ganesh Ramchandran of BEL can never be forgotten. All of them have not only encouraged but directly helped me to fabricate and modify circuits even in desert to make the system work. Thereafter, these changes were incorporated in the systems, which had gone for final acceptance tests.

Needless to say that this mobile troposcatter systems were also contributed by many others in fields of Antenna, and mechanical structures being mounted on vehicles. Some of them are no more, but their support and contribution during field trials can never be ignored. The extensive multi-disciplainary field trials, which were primarily led by the author have provided many insights to what our defence forces need. And the concept of using LEO satellite for next generation of satellite communication systems is the outcome of this.

Finally paying regards to all in DESIDOC, without whose support the monograph could never see the light of the day.

With regards to all and apologies to many others, who could not be mentioned individually

Atis D Mitra

List of Acronyms

AM	Amplitude Modulation
ASK	Amplitude Shift Keying
BPSK	Binary Phase Shift Keying
DAMA	Demand Assigned Multiple Access
DFE	Decision Feedback Equaliser
DFT	Digital Fourier Transform
DPLL	Discrete Phase Locked Loop
DSSS	Direct Spread Spectrum System
EFS	Error Free Seconds
FM	Frequency Modulation
IFT	Inverse Fourier Transform
LEO	Low Earth Orbiting
LO	Local Oscillator
MEO	Medium Earth Orbiting
NCO	Numerically Controlled Oscillator
NMS	Network Management System
OCS	Overseas Communications Service
OFDM	Orthogonal Frequency Division Multiplexing
PDC	Pre Detection Combiner
PLL	Phase Locked Loop
PM	Phase Modulation
PSD	Power Spectral Density
PSTN	Public Switched Telecommunication Network
QAM	Quadrature Amplitude Modulation
QPSK	Quadrature Phase Shift Keying

QR	Qualitative Requirement
SCPC	Single Carrier Per Channel
SDH	Synchronous Digital Hierarchy
SDR	Software Defined Radio
SSMA	Spread Spectrum Multiple Access
UWB	Ultra Wide Band
VCO	Voltage Controlled Oscillator

CHAPTER 1

Introduction

Satellites as tools of communications technology are presently available in primarily two versions–broadly termed as geostationary and orbiting types. The purpose and use of satellites don't require any detailed elaboration to most of the readers, as it is assumed that all of us, the targeted readers, are aware of these at some basic level. The basic attributes and the usage of satellites to communication technology can broadly be mentioned in a basic introductory form as follows:

Geostationary–It applies to those satellites which virtually look to be placed at the same place in the sky from the earth for all their active period of functioning. Thus, the communicating antenna from any point of the earth can be kept in static (time invariant) orientation looking to the satellite, which seems static from the earth, to be requiring practically no alignments (other than periodic long term ones). We assume that while communicating, user terminals are stationary or nearly stationary, as is the case in most of the times. The alignment of both Tx and Rx antennas of the ground-based assets such as user terminals and the ground control station/communication hub are directed along the vectorial direction aligning broadly with the stationary line from the observation point on earth's surface and the satellite. Thus, when the user terminals are placed on a moving platform, the antenna of the terminal needs to maintain its direction along the straight line from the ground location towards the satellite, thus requiring a compensation to the movement of the platform. In technical terms, such satellites are also called geosynchronous as its rotation around the earth matches the rotation of the earth around its own axis, to make it look stationary from any point on the earth's surface. Both the terms

geostationary and geosynchronous mean same thing and the terms would be used interchangeably in this monograph.

Orbiting–All satellites other than geostationary ones are orbiting. They orbit around the earth, as from any point on earth they look to be moving continuously in the same direction as per a time schedule depending on orbit period at fixed time intervals. Thus, if these are used for communications, the communicating antenna from the user terminal or the ground-based communication hub need to be kept on a continuously changing orientation to look towards the satellite, till it is visible. To communication engineers, it means that the antenna needs to be continuously requiring alignment to look towards the satellite from the ground location. In next sections, we shall be very briefly mentioning some of these parameters of the satellites, which are necessary to a communication engineer as a background.

One of the basic attributes of the two types of the satellites is in its visibility zones. From application point of view of communication engineers, the visibility zone of a particular geostationary satellite is fixed on 24×7 basis to the point on earth where it is visible, on the contrary the visibility zone of an orbiting satellite spreads around the world along its orbit; thus at any point on the visibility path on earth, the visibility stands only for some time periodically depending on the orbit of the satellite, but not on 24×7 basis. Thus, based on this fact it is understood that in a designated geographical zone, multiple orbiting satellites will be required to provide visibility on 24×7 basis to an area, while a single geostationary satellite can serve this purpose. This visibility of either a geostationary satellite or a group of orbiting satellites in the designated geographical zone is used as the basis of satellite communication technology to maintain communication connectivity between various user terminals present in the zone. This monograph is primarily meant to discuss the basic circuit implementation issues, and the ways to resolve some of the issues specially for orbiting, especially, LEO (Low Earth Orbiting) satellites with respect to a star configuration of the network, as we shall discuss subsequently.

Thus on a simplistic assessment, it is the antenna orientation or the antenna direction as a function of time, which arises as an immediate issue of concern to communication engineers, which need to be considered while planning to use orbiting satellites in communications. Similarly in case, the user terminal is on a mobile platform, some form of control of antenna orientation is needed even when the satellite is a geostationary one.

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About the Book

The development of geosynchronous satellite based briefcase terminal development has been over initiating very encouraging response from our defence and para military forces in late decade, i.e., precisely from 1997 onwards till 2010. Since inception, the demand has been to increase the capacity, not only tremendously, but also to look into increasing the operational zones beyond our borders even- which was not possible in the conventional way.

Further considering the indigenous expertise, the author has felt the limitations of using geosynchronous satellites for such communications exclusively for defence forces as there are tremendous demand for geosynchronous satellites for many other vital areas of civil needs, particularly for disaster management, agricultural applications and internet for transportation applications. Additionally, geosynchronous satellites being primarily deployed in equatorial orbits, limits quantitative availability, exclusively for India.

Keeping this in view, the proposal wasinitiated to write a monograph on the issues of the problems in development of a communication system based on LEO satellites. LEO satellitesare planned for defence forces, but for other applications. However additional minor modifications for communications can easily be incorporated.The launching of such satellites is available and considering the low orbits, these do not come under regulations of international bodies like the geosynchronous ones. The major advantage is its security against intentional jamming by adversaries and easy upgradations with lower costs.

The issues for practical aspects are not available in published literature. In case such a project is taken up, this monograph will provide the background to all to initiate the developmental effort.Thus it is only the initial attempt to begin the process. The implementation of the system is definitely realisable indigeneously, though quite complicated. Towards this objective,this monograph had been an attempt discussing sequentially in a story telling way. It explains some of the important aspects of the development issues.

About the Author

Shri AD Mitra with 38 years of experience of research and development in the area of communications, has seen the transition from analog to digital processes and its applications. Broadly, he has been the key person for both DIGITAL TROPOSCATTER COMMUNICATION SYSTEMS and BRIEFCASE-BASED SATELLITE COMMUNICATION SYSTEMS from concept to acceptance by the end users. Additionally, he was the leader for getting a LOS communication system type approved by Department of Telecommunications, Government of India through a specific field trial as a separate responsibility, independent of his technical activities.

He had been a member of board of courses of study in Indian School of Mines, Dhanbad and presently is also member of board of courses of study in Birla Institute of Technology, Mesra. The experience of interactions with the professionals involved in teaching and research in academic institutions and students has also enriched the author in sharing personal experience with professionals in DRDO. These experiences have resulted the outcome through the format of a monograph in an area yet not planned as on date to use LEO satellites, in a way similar to cellular mobile telephony. He has published a number of research papers in various journals, both in India and international ones. He had been a pioneer in development of frequency synthesisers in early eighties in India.

He has two text books under the title 'Digital Communications' for B Tech courses and 'Design Approach for Wireless Transmission in Digital Era' to provide refresh to researchers planning to work in advanced wireless transmission systems.

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