BULLETIN
OF "CAROL I" NATIONAL DEFENCE UNIVERSITY

https://buletinul.unap.ro/index.php/en/

Literature Survey on Meteor Burst Communication System

Assist. Prof. Muhanned AL-RAWI, PhD*

*Bandung Institute of Technology, Department of Electrical Engineering and Informatics, Bandung City, Indonesia
e-mail: muhrawi@yahoo.com

Abstract

A technology that has taken many years to develop is the foundation of Meteor-burst Communications (MBC). Many MBC systems have been installed and tested successfully. MBC systems comprise dynamic vehicular networks, fixed station networks, and point-to-point links. Currently available systems include medium data rate message handling, low data rate telemetry, and high-speed conversational voice advancements. In addition to describing the systems and technology currently being developed, this paper summarises earlier work in the field.

Keywords:
meteor burst communication; literature survey; applications.

Article info
Received: 12 May 2025; Revised: 4 June 2025; Accepted: 6 June 2025; Available online: 27 June 2025

Citation: Al-Rawi, M. 2025. "Literature Survey on Meteor Burst Communication System". *Bulletin of "Carol I" National Defence University*, 14(2): 215-222. https://doi.org/10.53477/2284-9378-25-24 https://doi.org/10.53477/2284-9378-25-24

1. Introduction

The radio propagation mode known as meteor burst communications (MBC), or meteor scatter communications, uses the ionised trails left by meteors during atmospheric entry to establish short communication links between radio stations up to 2,250 kilometres (1,400 miles) apart. Radio waves can scatter either forward or backwards, as seen in Fig.1.

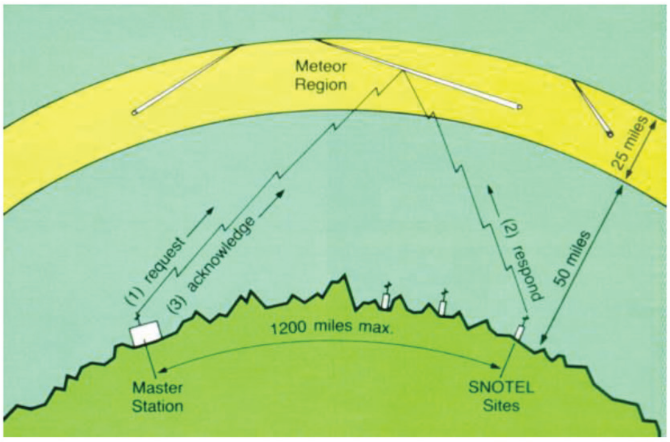

Figure 1 Meteor scatter propagation

1.1. How Meteor Communication Works

Millions of particles called meteoroids, that enter the Earth's atmosphere daily as it travels through space, have characteristics that make them suitable for point-to-point communication. In the E layer of the atmosphere, these meteoroids produce a luminous trail of ionised particles known as a meteor when they start to burn up. This trail may last for several seconds. Radio waves can be reflected by the ionisation trails because they can be extremely dense. The intensity of the ionisation produced by the meteor, which is frequently a function of the particle's initial size, determines the frequencies that can be reflected by any given ion trail. These frequencies are typically between 30 MHz and 50 MHz.

The altitude at which the ionisation occurs, the location of the meteoroid's descent over Earth's surface, the angle of entry into the atmosphere, and the relative positions of the stations trying to establish communications all affect the distance over which communications can be established. These ionisation trails provide only fleeting windows of communication opportunity because they only last anywhere from a few seconds to fractions of a second.

1.2. Military Use

One of the first significant deployments was "COMET" (COmmunication by MEteor Trails), which was used to communicate over long distances with the headquarters of NATO's Supreme Headquarters Allied Powers Europe. With stations in the United Kingdom, France, Italy, West Germany, Norway, and the Netherlands, COMET started operations in 1965. Depending on the season, COMET maintained an average throughput of 115–310 bits per second.

Beginning in the late 1960s, as satellite communications systems became more widely used, interest in meteor burst communications declined. It was discovered in the late 1970s that the satellites were not as widespread in their utility as first believed, particularly in areas with high latitudes or signal security considerations. Due to these factors, although its continued functionality is unknown, the U S. Air Force installed the Alaska Air Command MBC system in the 1970s.

More recently, Science Applications International Corporation (SAIC) established a testbed called the Advanced Meteor Burst Communications System (AMBCS) with Defence Advanced Research Projects Agency (DARPA) funding. AMBCS significantly increased the data rates, averaging 4 kbit/s, by using phase-steerable antennas pointed at the appropriate region of the sky for each time of day, in the direction that the Earth is moving "forward.". Satellites are significantly more expensive to operate, even though their nominal throughput may be roughly 14 times that of terrestrial networks.

The application of real-time steering could theoretically lead to further throughput gains. The fundamental idea is to aim the antenna at the precise location of the ion trail, or in certain situations, multiple trails at once using backscattered signals. Gain is increased as a result, enabling significantly higher data rates. According to what is currently known, this strategy has not yet been tested experimentally.

1.3. Armature Radio Use

The majority of meteor-scatter communication takes place between radio stations that follow a strict transmission and reception schedule. Stations attempting meteor-scatter communications must repeatedly transmit the same information until they receive an acknowledgement of reception from the other station because it is impossible to predict whether a meteor trail will be present at a suitable location between two stations. To control the flow of information between stations, established protocols are used. A complete information exchange frequently takes multiple meteors and a considerable amount of time to accomplish, even though a single meteor may produce an ion trail that supports multiple steps of the communication protocol.

Meteor-scatter communications can be conducted using any type of communications mode. In order to communicate with other stations during meteor showers without arranging a schedule beforehand, amateur radio operators in North America have been using single-sideband audio transmission. Morse code has been more widely used in Europe, where amateur radio operators have been sending messages at up to 800 words per minute using modified tape recorders and later computer programs. In order to replicate the transmission's content, stations that receive these informational bursts record the signal and replay it more slowly. Voice and Morse code communications have been supplanted by a number of digital modes implemented by computer programs since 2000. The WSJT-X software implements MSK144, the most widely used mode for amateur radio operations.

2. Literature Survey

This section elaborates briefly on the previous works related to the meteor burst communication system in the current century.
The possibility of creating a communication channel through meteor bursts has been known for decades, according to research done by the authors in (Fabrés, et al. 2002). The idea of providing new wireless services at a low cost has sparked renewed interest in recent years. In order to meet the strict size requirements while maintaining good gain and polarisation purity, this paper suggests a novel mobile terminal antenna.

The article in (Antipov 2006) examines the ways to boost the throughput of meteor burst communication as well as the prospects for expanding its active radius. It is demonstrated how to reduce the error of time standard synchronisation by way of the meteor burst channel.

In (Yabin, et al. 2010), the geometry relationship between the heliocentric and geocentric space of sporadic meteors is constructed, and the development of modelling meteor radiant distributions is examined. Theoretical prediction models are developed for the channel parameters of Meteor Burst Communication (MBC). The MBC links use these models. These models predict outcomes that are in good agreement with observational data. The channel parameters' prediction models, which are provided here, can be useful in building a meteor communication system.

The variable rate data transmission should be used to increase the system average throughput in light of the meteor burst channel's characteristics (Cai, et al. 2010), which causes equalisation and channel tracing issues at the receiver. Though it is thought to be the best detection method, the joint data and channel estimation of maximum likelihood sequence detection using the per-survivor processing (PSP) principle has significant computational complexity, which makes it difficult to keep up with the meteor channel's decline. A few states in the trellis diagram are selected by the time-varying threshold based on the exponential decay of meteor channels, and the adaptive state reduction of the PSP (ASRP) algorithm is used based on the estimation of the system parameters. ASRP is demonstrated to be able to provide dependable data transmission for adaptive modulation and coding of the meteor burst communication system while also offering a good trade-off between computational complexity and performance.

In (Li and Zhu 2010), the authors employ high-speed wired links to connect the base stations in accordance with the ring topology structure in order to overcome the network reliability issues. They also construct a meteor burst communication network using the stop-wait protocol. Based on the Opnet platform, the authors examine and model the packet length and rate.

A novel automatic repeat request (ARQ) scheme, called the Go-Back-i-symbol (GBi) ARQ scheme, was proposed by the authors in (Mukumoto, et al. 2012) and is appropriate for Meteor Burst Communications (MBC). The scheme uses the Viterbi decoding algorithm for convolutional codes to achieve symbol-wise ARQ. For packet communications over time-varying short burst channels, like meteor burst channels, we also suggest a workable transmission protocol that applies the GBi-ARQ scheme. Computer simulations are utilised to assess the fundamental performance of the GBi-ARQ scheme in MBC. By contrasting the performance of the GBi-ARQ scheme with that of a traditional block-wise ARQ scheme, its effectiveness is demonstrated.

OPNET-based channel modelling and simulation for meteor burst communications are proposed in the paper (Yi, et al. 2015). In order to develop a realistic simulation scenario of meteor burst communications, multi-layer node models of the master station and slave station are presented after an analysis of the properties of the under-dense meteor burst channel. The simulation procedures for both full-duplex and half-duplex communication are used to carry out the simulation. The findings showed that full-duplex communication outperforms half-duplex communication in terms of effectiveness and that the OPNET-based channel model is very well-suited for meteor burst communication.

The authors in (Sulimov, et al. 2017) discuss the issue of nonreciprocity of propagation conditions in MBCSs, or meteor-burst communication systems. Previously, this issue had not received enough attention in publications. Advanced communication systems like meteor key distribution systems, which are designed to safely generate two identical copies of a shared secret key at both channel sides, and meteor synchronisation systems, which have nanosecond precision, may be significantly impacted by the channel nonreciprocity. The foundation of these systems is the processing of phase characteristics of meteor radio reflections, which require precise modelling. A rigorous solution to the issue of radio wave oblique diffraction on ionised meteor trails serves as the foundation for our new MBCS simulation model. A more thorough examination of the channel nonreciprocity effects is made possible by our diffraction approach, which enables more accurate simulation of the amplitude and phase characteristics of oppositely propagating signals. The authors demonstrate the adequate immunity of MBCS to ionospheric disturbances even when operating in harsh polar region conditions by presenting some initial simulation results on the channel nonreciprocity at meteor-burst propagation.

https://doi.org/10.53477/2284-9378-25-24

The purpose of the research in (Wada, et al. 2018) is to investigate whether Meteor Burst Communications (MBCs) could be used in equatorial areas. In Indonesia, researchers set up the remote and master stations in Jimbaran on Bali Island and Yogyakarta on Java Island, respectively. They verified, as a preliminary experimental result, that meteor burst channels were used to transmit some packets between the two stations.

The purpose of the article in (Voronin, Doroshenko and Ksenofontov 2019) is to support the value of using meteor communication networks as a basis for communication on the access connectivity network for vessel traffic management along the northern sea route's coastal zone on the route to the Arctic Russian infrastructure. From the perspective of system analysis, it gives us the generalised mathematical model of the network made up of the radiotransmitter and receiver, antenna systems, and structural-functional scheme, which are the main options that describe the telecommunication technologies of meteor connection. Using adaptive antenna grids as UHF antenna systems is such an example.

The technology for building a promising code division multiplexing meteor-burst communication system (MBCS) is presented in the paper (Holovan and Kharchenko 2020). In addition to improving the system's noise immunity and covert operation, it expands the bandwidth. Software-defined radio (SDR) is the foundation of the suggested technology, which uses software parameter control of the signals and their transfer protocols to enable MBCS adaptation to environmental conditions. It involves the best possible reception and matched digital filtering of large-base signals, and it includes a method for creating a large ensemble of signals with a direct sequence spread spectrum and enhanced auto- and cross-correlation properties. It is suggested to implement narrow-band interference rejection in the signal spectrum in conjunction with matched filtering software to increase noise immunity. The methods for synchronisation and detection that functioned well under non-Gaussian and non-stationary interference conditions were taken into account. A pseudorandom permutation of codeword elements of a maximum-length register code has been used in software to create a large ensemble of direct sequence spread spectrum signals with enhanced auto- and cross-correlation properties. Field-programmable gate arrays (FPGAs) have been used to implement algorithms for digital matched filtering and interference rejection as applied to large-base signals, which were designed using fast Fourier transforms. Software based on an FPGA has been developed for the detection and synchronisation of large-base signals.

The first attempt to investigate the potential existence of ionised meteor trails that offer combined forward and backwards scattering of radio waves at radio links larger than 300 km is made by the authors in (Lapshina, et al. 2021). The authors suggest a model for their computer simulation and refer to these meteor trails as "Forward-Backward Scattering," or simply FBS-trails. According to the authors, there are a number of real-world uses for the FBS-trails, such as accurate time synchronisation of passive remote stations. According to simulation results, the nearly transverse orientation of the FBS-trails with respect to the axis of the meteor-scatter radio link is their most dependable distinguishing characteristic. FBS-trails are less likely to occur over longer radio links, and nearly all detections come from meteor trails that only provide forward scattering, which is the only direction of travel. Between one percent (at meteor-scatter links longer than 1500 km) and roughly ten percent (at meteor-scatter links shorter than 150 km), the proportion of FBS-trails in the total number of detected meteor events varies with link length.

Applying a multi-receiver system to the MBC is suggested in the paper (Takumi, Kaiji and Tadahiro 2023), which also examines three approaches for combining each receiver's reception: individual reception, soft value combining, and log-likelihood ratio combining. By considering the position distribution of meteor bursts and the direction of each receiving antenna, the paper illustrates the communication performance of the multi-receiver system using the three combining methods in MBC.

Through an analysis of the technology's principles, features, application scenarios, and emerging trends, the paper in (Gao 2024) came to the conclusion that meteor trail communication is a viable way to connect locations that are challenging to reach with other means. Additionally, this paper highlights certain shortcomings that could be improved in the future, allowing MBC to increase its effectiveness and adapt to more circumstances after resolving the current issues. This paper attempts to inspire experts who are willing to improve MBC by providing them with useful information by summarising all those aspects of this technology. This will enable them to create a better communication network using the modified MBC system.

3. Summary

This paper dealt with one of the most important technologies in the field of telecommunication systems, which is meteor bust communication system. The paper explained how this technology works and its applications in military use and amateur radio use. Also, the paper briefly described some of the previous works in the technology mentioned.

References

Antipov, I.E. 2006. "Expansion of the Application Fields and Development Perspectives of Meteor Burst Radio Communication and Synchronization." *16th International Crimean Microwave and Telecommunication Technology.* Sevastopol, Ukraine. pp. 967-968. doi:10.1109/CRMICO.2006.256279.

Cai, Jueping, Zan Li, Xiaojun Chen, and Benjian Hao. 2010. "An adaptive receiver of joint data and channel estimation for meteor burst communications." *International Journal of Communication Systems* 24 (6): 745-760. http://dx.doi.org/10.1002/dac.1182.

Fabrés, Marta Cabedo, Juan Escudero Vilar, Miguel Ferrando Bataller, and Alejandro Valero Nogueira. 2002. "Novel mobile terminal antenna for meteor burst communication systems." *Microwave and Optical Technology Letters* 34 (2): 80–83. http://dx.doi.org/10.1002/mop.10378.

Gao, S. 2024. "Analysis and Application of Meteor Burst Communication." *2024 4th Asia-Pacific Conference on Communications Technology and Computer Science (ACCTCS).* Shenyang, China. pp. 800-804. doi:10.1109/ACCTCS61748.2024.00147.

Holovan, O.V., and V.M. Kharchenko. 2020. "Constructing technology of a meteor-burst communication system with code division multiplexing." *RADIOFIZIKA I ELEKTRONIKA* 25 (2): 74-81. http://dx.doi.org/10.15407/rej2020.02.074.

Lapshina, I., S. Kalabanov, A. Karpov, and A. Sulimov. 2021. "Analysis of meteor trails providing combined forward and backward scattering of radio waves", ." *Planetary and Space Science* Vol. 195. https://doi.org/10.1016/j.pss.2020.105135.

Li, Qing, and Lidong Zhu. 2010. "Modeling and simulation of Meteor Burst Communication network." *2nd International Conference on Signal Processing Systems.* Dalian, China. pp. 332-335. doi:10.1109/ICSPS.2010.5555792.

Mukumoto, Kaiji, Shinsuke Nagata, Tadahiro Wada, and Koji Ishibashi. 2012. "Proposal of Go-Back-i-symbol ARQ Scheme and its Performance Evaluation in Meteor Burst Communications." *IEEE Transactions on Communications* 60 (8): 2336-2343. doi:10.1109/TCOMM.2012.071912.110330.

Sulimov, Amir I., Arkadiy V. Karpov, Irina R. Lapshina, and Rustem G. Khuzyashev. 2017. "Analysis and Simulation of Channel Nonreciprocity in Meteor-Burst Communications." *IEEE Transactions on Antennas and Propagation* 65 (4): 2009-2019. doi:10.1109/TAP.2017.2669730.

Takumi, Kayama, Mukumoto Kaiji, and Wada Tadahiro. 2023. "A Study on Application of Multi-Receiver System in Meteor Burst Communication." *IEICE Tech. Rep.* 122 (429): 7-12.

Voronin, S., V. Doroshenko, and Y. Ksenofontov. 2019. "Radiochannels of Meteor-Burst Communication Network of the Northern Sea Route." *Proceedings of Telecommunication Universities* 5 (3): 13-18. doi:10.31854/1813-324X-2019-5-3-13-18.

Wada, Tadahiro, Kaiji Mukumoto, Hiroki Wadaguchi, I Wayan Mustika, and Linawati. 2018. "Preliminary experiment of meteor burst communications in equatorial region."" *IEICE Communications Express* 7 (2): 43-47. http://dx.doi.org/10.1587/comex.2017xbl0136.

Yabin, Zhang, Hu Dazhang, Lin Leke, and Guo Yuquan. 2010. "Diurnal Variability Prediction Model of Meteor Burst Communication Channel." *Chinese Journal of Space Science* 30 (1): 60-65. http://dx.doi.org/10.11728/cjss2010.01.060.

Yi, Zhao Xiang, Yong Xian, Xiong Mei Zhang, Hua Peng Zhang, and Xiao Dong Mu. 2015. "Simulation and Analysis for Meteor Burst Communications Based on OPNET." *Applied Mechanics and Materials.* Vol. 738-739. pp.1205-1208. http://dx.doi.org/10.4028/www.scientific.net/amm.738-739.1205.