TECHNOLOGIES FOR RURAL APPLICATION USING METEOR BURST

Dr. Elsadig Gamaleldeen Elsadig
Applied Physics and Computer Science
Omdurman Ahlia University
elsadigg@gmail.com

ABSTRACT

There has been increasing interest in utilizing meteor burst systems communications
Which had been known for several decades and there has been many past experimental programs to explore the usefulness of meteor reflections for communication purposes. The renewed interest in meteor burst communications stems come from need to enlarge the applications that can be used by it. The objective of this study was to respond to a request to use meteor burst communication applications for rural areas and describe some of the real-world applications .The applications, usage, and technology for meteor burst systems are undergoing continual change and improvement.

Keywords: wireless network, meteor burst communication, rural area communication.

1. INTRODUCTION

The daily occurrence of billions of meteor trails in the Earth's upper atmosphere presents a powerful opportunity to use the trails environment as a communication media .Meteor burst takes advantage of the fact that radio waves are reflected off of the ionization trails of meteors which enter the Earth's atmosphere. It is well suited for many applications. MBC offers better security compared to other long range communication systems because of its low probability of intercept .

2. METEOR BURST COMMUNICATION

A meteor burst communication system (MBCS) utilizes as a means of radio signal propagation ionized meteor trails that exist in altitudes of the 80 to 120 Km region of the earth's atmosphere [3]. These trails reflect or actually re-radiate the RF energy (usually in the low VHF range of from 40 to 100 MHz, It is generally acknowledged that the optimum band for normal operation is 40-50 MHz) from a transmitting source to a recovery terminal. The height of the trails allows over-the-horizon communication at distances up to 1200 miles [4]. However, because the ionized trails exist for only short periods of time (usually from a few milliseconds to a few seconds) communication is intermittent and high speed digital pulse transmission techniques must be used to convey the information. The system is particularly suited to long range, low rate data acquisition applications but it can also support a low speed (100 words/minute) teletype link [5]. Shorter operational ranges, over mountainous terrain, are also a capability due to the height of the reflective meteor trail.

The major difficulty with MBC is that an ionization trail must be correctly orientated in the correct area of the sky between stations for communication to take place. The average time between usable trails varies according to known daily and seasonal cycles in meteor arrival rates, as well as being dependent on the transmitter power and the antennas used. Current state-of-the-art systems have delays of less than a second between usable trails. The channel is still sporadic however, and this means that MBC is most suited to data transmission, as opposed to real-time voice or video.

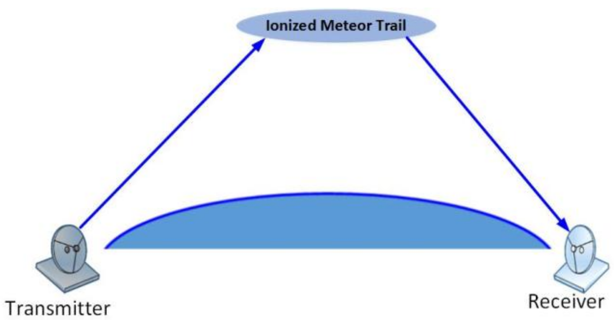

Figure (1) Reflection of radio wave off ionized meteor trail

The early growth of MBC was stunted in the mid 1960's by the development of satellite communication systems [6]. With the growing awareness of the limitations of satellite systems, particularly under tactical conditions, interest in MBC has increased. As MBC systems become more operationally acceptable, technological improvements to current system weaknesses will be developed.

Whenever a meteor creates a reflected pathway between the transmitter and the receiver, the antenna of the receiver can collect the short sample of data sent from the transmitter.

3. THE METEOR BURST COMMUNICATION (MBC) NETWORK

The MBC network can be divided into the radio frequency (RF) part and the data transfer and processing part, as shown in the figure below.

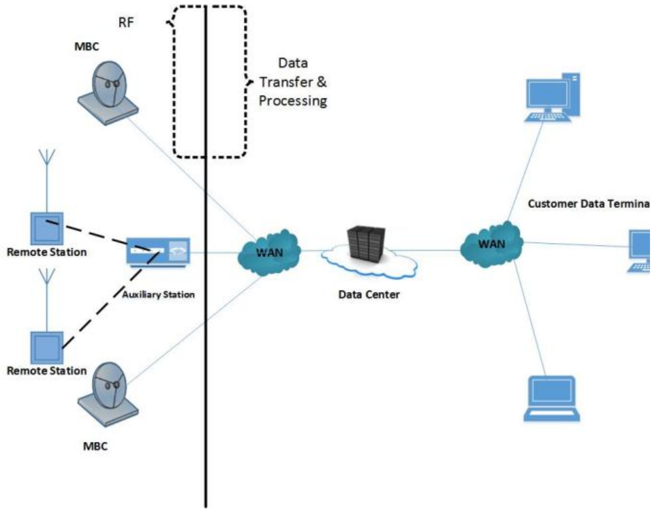

Figure (2) MBC Network System Overview

The number of Meteor Burst Base Stations (MBBS) depends on the size of the area which has to be covered [7].

The Meteor Receiver is based on Meteor Burst Communications (MBC), a technique that exploits meteors to create a temporary communication channel between two nodes [8, 9]. Implementation of MBC involves a transmitter and an out-of-sight receiver, typically hundreds of miles apart. When a satellite or meteor travels overhead, the radio wave will reflect off of the object and back towards the receiver.

4. METEOR TRAIL IONIZATION

Billions of ionized meteor trails are produced daily in the earth's atmosphere at heights of 80 to 120 Km these trails diffuse rapidly and usually disappear within a few seconds [10]. However, during their brief existence, they will reflect radio waves in the VHF frequency range.

The meteor, as it enters the upper atmosphere traveling at speeds of 10 to 75 Km/ second, possesses a large amount of kinetic energy. As it begins colliding with air molecules, much of this kinetic energy is converted into heat which effectively vaporizes atoms from the surface of the parent meteor. These vaporized atoms, which are traveling at about the same speed as the meteor, are further restricted by air molecules especially as they progress further into the atmosphere. This results in the transformation of kinetic energy into the energy of ionization which effectively strips electrons from the atoms leaving a trail of positive charged ions and free electrons. It is the electrons that reflect or re-radiate radio waves.

5. THE ADVANTAGES OF MBC

These are include

• Low price. Ionized trails are free and the communication hardware is relatively cheap.

- Robustness. The ground stations are simple and reliable.
- Meteor trails 'cannot be shot down', which makes MBC attractive for military applications.
- The transmission is largely impervious to electrical interference, such as polar and auroral disturbances.
- Suitability for remote use. MBC systems have a range of up to 2000km, and due to their robustness and low power consumption the ground stations have low maintenance requirements.
- Resistance to ground interception and jamming [11]. The small footprint of the reflection means that to intercept or jam the signal requires being close to the receiving ground station.

6. MBC RURAL APPLICATION

For applications requiring greater data throughput and shorter waiting time, the transmitter power may be increased towards the practical limit. For example [12], The Alaskan Air Command MBC System uses 10 kW transmitters feeding high gain antennas to deliver their long range surveillance radar data to the command center.

An improvement in the overall performance of an MBC system could be obtained from a dynamically adaptive bit rate system because of the widely varying characteristics of the meteor burst channel. Bursts vary widely in intensity and length on any particular path. The practical effectiveness of using such an adaptive modem would depend on its ability to rapidly decide the receiver channel quality and send its decision to the transmitter at the other end.

6.1 MILITARY APPLICATIONS IN ELECTRONIC WARFARE ENVIRONMENT

MBC is the relative immunity to ground intercept or jamming. Due to the extremely small footprint of MBC signals (about 50km by 20km) [13], a site would have to be exceptionally close to hostile installations for interception to take place. Jamming by hostile forces using a meteor-burst mode would also have little chance of success, as the jamming signal would have to arrive at the same time as the desired signal. This is unlikely to happen unless the hostile transmitter is utilizing the same meteor trails as the friendly one, which it cannot do unless it has near-identical system characteristics. Such characteristics would include location, and in this situation.

6.2 TACTICAL COMMUNICATIONS

There are several areas of tactical communications, however, where speed of transmission and message wait times are not the critical service criteria. For some applications, availability, redundancy, or covertness may be more important communication considerations than throughput. Within its limitations, MBC may be capable of providing several of these communication services in a tactical environment.

6.3 TEXT MESSAGES

MBC is capable of providing a communication path for text messages. It can do this on single, point-to-point links or with networks connecting many stations. The networks are examples of the MBC text message capability. This type of functional application could be beneficial for low priority, administrative message traffic. MBC could be used as an overload circuit when long range, communication channels are clogged with high precedence message traffic [6]. Often under conditions of high operational tempo, low priority, administrative traffic does not get through or is greatly delayed. MBC is a method to increase communication capacity when additional satellite channels or useable HF frequencies are not available.

Text messages are often relatively short on tactical command circuits. Standardized formatting of messages, also helps to reduce their lengths. With MBC, shorter messages mean reduced waiting times. An MBC system with short, formatted messages could be useful as a backup to higher throughput systems that are vulnerable to enemy or environmental threats.

6.4 DATA MESSAGES

Data messages, are messages that are directly used by machines, instead of people. MBC by its nature is a data communication technique. It could be employed to send data messages that do not require "real time" reception. As an example of the [5] "real time" requirement, a fire control, radar system needs very rapid updates of the position and range of its target. A long range radar may only require updates by the minute.

6.5 Sensors

Tactical sensor systems are employed to provide intelligence on enemy activity and other environmental factors. Traffic movement on key avenues of approach is an example of information commonly delivered by sensors. Sensors are usually hidden in enemy territory by covert ground forces or dropped by aircraft. The range within which sensors can operate is often limited by the communication methods used by the systems. The SNOTEL (Snow Telemetry) [9] network has demonstrated the effectiveness of MBC for controlling a large number of remotely located sensors. The operating distances of the SNOTEL system are comparable or greater than most tactical sensor systems.

6.6 ORDER WIRES

Order wire circuits are informal, communication channels dedicated to controlling specific functions. An example of an order wire circuit is a communication engineering circuit, used to control and coordinate all the other communication circuits linking an organization. Often these order wire circuits must "take up space" on the precious, beyond-line-of-sight communication (BLOS) path they are trying to control [14]. When the BLOS path experiences an outage, the control circuit used to restore the outage is lost as well. MBC can be used to both, relieve the burden of providing channel Order wire circuits are informal, communication channels dedicated to controlling specific functions. An example of an order wire circuit is a communication engineering circuit, used to control and coordinate all the other communication circuits linking an organization. Often these order wire circuits must "take up space" on the precious [15], BLOS communication path they are trying to control. When the BLOS path experiences an outage, the control circuit used to restore the outage is lost as well. MBC can be used to both, relieve the burden of providing channel.

6.7 NUCLEAR ENVIRONMENT

Extreme disruptions in communications can be expected during and after nuclear attack. There are strong possibilities that communication satellite systems will be degraded, if not destroyed. HF radio systems, depending on the ionosphere for BLOS communications, will also be vulnerable. Nuclear detonations can temporarily disrupt large portions of the ionosphere [16], causing HF blackouts that may interrupt communications for "hours or days". MBC does not depend on the ionosphere as a propagation path. It is relatively immune to the ionosphere disturbances caused by nuclear detonations. MBC is "somewhat affected" by the increased D-layer absorption, that will occur in nuclear environment, but it will “recover several hours before HF sky wave" communications. This robustness of MBC communications in a nuclear environment has lead several agencies to study its applications for Tran- and post attack, reconstitution efforts. The Federal Emergency Management Agency (FEMA) has established an experimental MBC network [17]. A recent test on the FEMA network demonstrated, that MBC could be successfully conducted with buried antennas, thus enhancing system survivability.

6.8 HIGH LATITUDE COMMUNICATIONS

High latitude is pole ward of 65 degrees latitude. Several factors contribute to reduced BLOS communications in the higher latitudes. Satellite communications at these latitudes is harder because of the difficulties acquiring a proper "look angle" to the equator [3]. Most tactical communication satellites have geostationary orbits above the equator. At the higher latitudes, antennas must be aimed with angles very low to the horizon in order to see" these equatorial satellites. To achieve these low angles, antennas must often be placed on the highest available terrain. Usually, in tactical situations, the "highest available terrain" is inhospitable, difficult to operate from, or vulnerable to the enemy. HF communications can be severely distressed at high latitudes. BLOS, HF communications is dependent on the ionosphere for a propagation path. In the higher latitudes, the ionosphere is often disrupted by auroral activity and polar cap absorption events. Auroral conditions serve to significantly reduce the range of frequencies that will be useable over a given HF communication path and introduces temporal and spectral variations on the radio signals. While the number of frequencies are reduced, rapid frequency changes are required to adapt to fluctuating ionosphere conditions. Polar cap absorption can cause HF "black outs" lasting several days. MBC is much less affected by these conditions. Since it is not dependent on the ionosphere, MBC does not need to change frequencies to adapt to polar events. Operating at higher frequencies than HF, MBC is less effected by absorption. MBC can experience some auroral and absorption effects during severe polar disturbances but to a far less degree than HF. MBC systems can experience a continuous, communication channel between several stations in the network. This will cause greatly increased throughputs and reduced wait times. Network protocols must be able to recognize this condition, however, and increase management functions, otherwise the individual stations contending for the channel will disrupt overall network efficiency.

The performance of a meteor burst link is defined, as the “wait time” required to transfer a message between two stations at a specified reliability. The primary system parameters that will influence this “wait time” are operating frequency, data rate, transmit power, antenna gain and receiver threshold level. Since there are different costs related to each of these parameters, it is important that flexibility is maintained in these areas so that the most cost effective system can be designed for each application.

Meteors occur randomly. Therefore, a natural time-division-multiplex access (TDMA) feature is inherent in all meteor burst networks. This TDMA feature allows thousands of stations to operate within a network on a single 25 kHz frequency channel providing highly efficient use of radio spectrum.

MBC systems can be employed effectively for both point-to-point services and multiple station networks for ranges up to 1600 kilometers. For extended ranges, relay stations are employed using data store-and-forward techniques. A meteor burst system can be fully automated so that it is simple and economical to operate. Its rapid deployment capability also makes it ideal for disaster and emergency communications.

7. CONCLUSIONS

MBC is a mature technology which is successfully filling the communication needs of several organizations. This paper has focused on the application of MBC techniques and communications for future use in rural area. To do this, both the theory of meteor trail propagation, and the design criteria, necessary to use this means of propagation was explored. The application of MBC was next developed, using general communication concepts, environmental applications, and specific communication examples. The analysis highlighted several strengths and weaknesses that MBC .

REFERENCES

1. Forsyth, P.A., Vogan E.L., and Hines, C.O., "The Principles of JANET - A
Meteor- Burst Communications System," Proceedings of the IRE, v. 45, p. 1642, December 1957.

2. Elliot, Ronald D., "Meteor Burst Communications In Tactical Intelligence Support," SICNAL, pp. 80-88, November 1986.

3. University of Wisconsin Department of Electrical and Computer Engineering, Contract number N00039-81-C-03.39, Feasibility of High Speed Digital Communications on the Aleteor Scatter Channel, by W.I'. Rirkemeir and M.D. Grossi, I May 1983.

4. Helweg, Gretchen Ann, leteor-Burst Communications: Is This What The Navy Needs?, Master’s Thesis, Naval Post Graduate School, Monterey, CA, June 1987.

5. Hoff, J.A., "The Utility of Meteor Burst Communications," AILCOAIA! , San Diego, CA, pp. 0565-0575, October 1988.

6. Heacock, Phillip K. Col USAF and Price, Frank D., "How the USAF Talks On A
Star!," POPULAR COMMUNICATIONS, p. 44, September 1984.

7. The Meteor Burst Communication Network System. 2015. *The Meteor Burst Communication Network System*. [ONLINE] Available at: http://www.itu.int/ITU-D/fg7/
case_library/documents/MBC001.html. [Accessed 12 April 2015].

8. Owen, Michael, "VHF Meteor Scatter An Astronomical Perspective," QST, pp. 14-20, June 1986.

9. Greene, Clarke, "Meteor Scatter Communications," QST, pp. 14-17, January 1986.

10. Oetting. John D., "An Analysis of Meteor Burst Communications for Military Applications," IEEE Transactions on Communications, V. 28, p. 1591, September 1980.

11. Defense Communications Agency, Options, Selection Rational and Recommendations for AIeteor Burst Communication Interoperability, Part I Initial Capability -DRAFT, 24 August 1987.

12. Vincent, W.R., Wolfram, R.T., Sifford, B.M., Jaye, W.E., and Peterson, A.M., "Analysis of the Oblique Path Meteor-Propagation Data from the Communications Viewpoint," Proceedings of the IRE, v. 45, p. 1701, December 1957.

13. Naval Ocean Systems Center, Contract NO:N66001-79-C-0460, Analysis of Mete or Burst Communications for Navy Strategic Applications, Meteor Communications Consultants, INC., San Diego, CA, February 1980.

14. Rome Air Development Center, RADC-TR-86-165, A Data Base Approach to Analysis of M1eteor Burst Communications Channel, by Weitzen, Jay A., Rome. NY. October 1986.

15. Morgan, Edward J., "The Resurgence of Meteor Burst," SIGNAL , p. 69, January 1983.

16. Bain, Walter F.,"VHF Meteor Scatter Propagation," QST, pp. 20-25, April 1957.

17. Naval Ocean Systems Center, Technical Report 1171, Buoy Relay for Xfeteor Burst Communications Systems: Test Report , Bickel J.E., et al., San Diego, CA, June 1987.

18. The ARRL Antenna Handbook, The American Radio Relay League, 9th ed., pp.160-167, Newton, CT, 1960.

19. Eshleman, V.R. and Mlodnosky, R.F., "Directional Characteristics of Meteor Propagation Derived from Radar Measurements," Proceedings of the IRE , v. 45, p. 1715, December 1957.