AX.25 PACKET RADIO COMMUNICATIONS USING METEOR SCATTER PROPAGATION

Results from experiments performed during autumn 1987

by

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1. GENERAL

1.1 Introduction

Meteor scatter propagation is commonly used in modern commercial and military digital communications. This traffic preferably takes place in the frequency range 30 to 50 MHz, where the reflectivity and duration of the meteor trails are the best. Meteor scatter links exhibit very reliable communication, even during periods of low meteor trail occurrence [2].

Among radio amateurs digital meteor burst communication has been discussed for many years. Despite this, no experiments on amateur basis have (to the knowledge of the author) been performed in Sweden or elsewhere in the world. During the past two years several amateurs have reported the random appearance of AX.25 packets from very distant stations. The propagation of these packets can only be explained by meteor scatter reflections. This supports the idea to exploit these reflections for packet radio links.

The following paper reports on the realization and results of an initial experiment with packet radio communication using meteor scatter propagation in the 144 MHz amateur radio band. The tests were carried out during the meteor shower Geminides in the midst of December 1987.

1.1 Purpose of the experiment

The main purpose of the experiment was to explore the possibilities of using meteor scatter reflections for packet radio communication in the 144 MHz band. The investigation involved measurement of channel throughput and delay during a major meteor shower.

2. BASIC PRINCIPLES

2.1 Occurrence of meteor trails

Particles in the form of meteoric debris with masses ranging from only a few milligrams up to several grams occur, with roughly uniform density, in all parts of the world on a virtually continuous basis. Observational data and theoretical predictions, verified by recorded statistics, indicate that more than 10^{12} meteor trails of a size sufficient to support radio communication enter the atmosphere on a daily basis. 'The incidence of usable meteor trails varies both diurnally and seasonally. Diurnal variations occur with a maximum about 06 AM and a minimum around 07 PM local time. The ratio of maximum to minimum occurrence ranges from 3: 1 to 4: 1. Seasonal variations exhibit similar characteristics in the Northern Hemisphere with a maximum in July and a minimum in February. Seasonal variations are opposite in the Southern Hemisphere [3].

Beside these seasonal variations in the mean meteor density, showers occur during short periods of time every year.

2.2 Trail ionization

Ionized meteor trails are created by the transfer of kinetic energy (related to the mass and speed of the meteor) from meteoric debris into the energy of ionization which leaves a trail of positively charged ions and free electrons. The free electrons form the medium for reflection or re-radiation of radio signals.

Two types of ionized trails are created. They ***are*** termed ***under-dense*** and ***overdense,*** and are typically categorized by the intensity of ionization in the trail. Underdense trails exhibit relatively small electron line densities in the range of 10 to 10^{14} electrons per meter. Underdense trails do not support sufficient ionization density to reflect radio signals. Instead, the individual electrons are excited by radio waves, and subsequently act as minute dipoles which re-radiate the signal. In meteor trails that exhibit electron line densities of greater than 10^{14} electrons per meter, a sufficient density of ionization exists to permit specular reflection of the incident radio signal.

These trails are termed overdense and the center part of the trail acts as a perfectly conducting cylinder.

Underdense trails are prevalent. However, overdense trails exhibit longer duration and lower attenuation than underdense trails.

2.3 Frequency dependence

Meteor scatter reflections vary strongly with operating frequency. Reflected or re-radiated signal amplitudes have been shown to be proportional to the inverse cube of the frequency ($1/f^3$) and its time duration is roughly proportional to the inverse square of the frequency (l/f?). The average duration of underdense trails is between 200 and 400 ms in the frequency range 30 to 50 MHz. Overdense trails may exhibit considerably longer duration - up to several tenths of seconds. With the above frequency considerations, the duration of underdense trails will be around 10 times shorter on 144 MHz than on 40 MHz, i.e. a mean duration of only 20 to 40 ms. This clearly demonstrates that underdense meteor trails can not be used for standard amateur packet radio traffic, since the packet length is roughly 0.8 seconds. The amplitude of signals on 144 MHz will be about 14 dB lower than corresponding signals on 40 MHz.

2.4 Maximum communication distance

The maximum range for a meteor scatter link is limited because of geometrical reasons. The reflection takes place at an altitude of 90 - 120 km and because of the earth's radius, the maximum communication distance is about 2 000 km.

3. EXPERIMENT SETUP

3.1 Selection of modulation form

The selection of a suitable type of modulation for the experiment system was done with great care. Signals propagated on meteor scatter paths are generally exhibiting small signal to noise ratios (SNR) and a doppler shift due to movements of the trail. Under these circumstances binary- phase-shift-keying (BPSK) was considered to be the most suitable modulation form. BPSK meets the need for low bit- error-rates (BER) at small SNR [4]. Furthermore, if the loop- bandwidth of the demodulator is correctly designed it is possible to accomplish a stable phase-lock on signals which differ from nominal frequency due to doppler effects. Finally, the hardware implementation of a BPSK-demodulator is straight forward.

3.2 Experimental hardware

Two identical experimental stations were constructed according to the following general specification:

Frequency band	144	MHz
Power output	150	W
Noise figure	<2	dB
Antenna gain	15	dBi
Antenna polarization	hor.	
Modulation	BPSK	
Bitrate	1200	bit/s
Protocol	AX.25 level 2 (ver.1)	

Heavy demands had to be put on transceiver frequency accuracy and long-term stability. ICOM-transceivers were tested prior to the test. IC-251E and IC-27l.E were finally chosen for the experiment system. The continuous transmit/receive switching puts heavy strain on the radio equipment, especially on the switching circuits in the linear amplifier and low noise pre-amplifier. To minimize this strain, a so called sequencer was constructed, which controlled the switching order of the transmitter and amplifiers.

Modems used in the experimental set-up were of G3RUH design [5]. This modem was originally designed for digital communication through the amateur radio satellite Fuji-OSCAR- 12. Only minor modifications had to be made for our needs.

The packet protocol AX.25 was handled by standard terminal node controllers (TNC), which had to be slightly modified to allow the connection of external modems.

3.3 Experimental software

The two stations were designed to be operated fully automatically. Hence it was necessary to write a computer program which controlled the link process and stored the results. The program was originally written in C-language in a UNIX environment, but was later translated to TurboBasic, running on IBM/XT. The master station was controlled by the computer. From this station all activities were initiated, according to a certain procedure; see below. The slave station was only running in “loopback-mode”, i.e. the TNC was provided with a loopback circuit in the terminal port, which allowed immediate retransmission of all correctly received packets.

A completed contact beween the two stations was realized according to the following procedure:

1. MASTER **continously** sends connect-frames **<SABM>**

2. SLAVE receives **<SABM>** and verifies by starting sending **<UA>-frames**

3. **MASTER** receives **<UA>,** stores the time on disk and starts the transfer of a standard file consisting of 400 bytes

4. When SLAVE receives an <I>-frame correctly, the frame will immediately be retransmitted, with updated "expected frame-number field"

5. When MASTER receives a correct **<I>-frame,** the next one will be transmitted

6. **When** all characters in the file have been transferred, the MASTER stores the time and starts sending <DISC>- frames

7. SLAVE receives <DISC> and sends **<UA>**

8. **MASTER** stores contact statistics, which are available from the TNC

9. **The** procedure is repeated

By this procedure a transfer of 400 bytes has been accomplished. Using the statistical functions supported by the TNC (DISPLAY HEALTH) is a convenient way to get detailed information on the link quality.

3.4 Time and station locations

The experiment was performed in the period 7 - 16 December 1987, i.e. during the meteor shower Geminides, which reached its maximum intensity on 12 December.

The master station **(SK5BN)** was located near Linkoping in the southern part of Sweden. The slave station **(SK2GJ)** was situated in Kiruna, above the Arctic circle which resulted in a great circle distance of 1100 km between the two stations.

5. RESULTS

On the second day of the tests, severe problems appeared caused by interference in the slave station receiver. The interference signals originated from two different sources. Reciprocal mixing between phase-noise in the receiver and the extremely strong signal from the VIE-beacon SK2VHG caused an increase in noise level by several dB, synchronuously with the keying of the beacon. Furthermore, man-made noise from the surrounding city contributed to the over-all noise level more than expected. The reciprocal mixing products were easily removed by a notch filter in the receiver input, but the over-all noise level was still too high to expect any success for the tests.

At this point, it was decided to change the experiment procedure, in that SK2GJ in Kiruna was to transmit continuously <SABM>-frames and SK5BN in Linkping was set to listen-only mode. All correctly received packets at SK5BN were stored on disk.

Furthermore, a mains power failure at SK5BN resulted in a loss of data after 13 December.

5.2 Extracted results

As an effect of the encountered problems with interference and power failure, the effective time :for the experiment lasted 10 December 4.30 PM to 13 December 8.30 AM local time. During this period totally 96 <SABM>-frames were correctly transferred beween the two stations.

It has not been possible to make any statistical conclusions from the very limited amount of data that was collected during the test. However, the results clearly show, the possibility of establishing 144 MHz packet radio links using meteor scatter propagation.

6. FURTHER EXPERIMENTS

In spite of the encountered problems, the results from the tests encourage towards further experiments. For instance, it would be interesting to establish a two-way-contact and to fully use the computer software that permits more statistical information to be collected.

The next experiment should suitably be assigned to the Persides in August 1988. If possible, the stations should be equipped with more output power, since 150 W is considered to be close to the margin. Also, extreme care should be taken to select proper test sites and to check the interference level in advance.

7. ACKNOWLEDGEMENTS

Finally, I would like to thank all people involved in the project team. Without their enthusiasm and skill, this experiment could not have been made. Working with a team ofdevoted people is a great opportunity which I appreciate immensely; and I am certainly looking forward to future projects within the group.

8. REFERENCES

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