NOISE FLOOR CONDITIONS DURING LONG DISTANCE RADIO COMMUNICATION

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ABSTRACT

The present work reports the typical noise floor conditions experienced by a radio communication station and the severe interference effect caused due to atmospheric radio noise to communication system. Emphasis is laid on different factors affecting the low frequency noise spectrum. Our study of the frequency spectra of atmospheric radio noise field strength at VLF band when superposed over the reported data indicates a significant decrease of the noise level from kHz to MHz band. The variation of the noise level at VLF exhibits a clear high values during the cloudy months, May to September. The spectral behaviour of the noise level has been examined considering the activity of the sources. The present study provides information about the wave propagation, propagation of the atmospherics itself and the mecanism of lightning discharges.

INTRODUCTION

Long distance propagation of radio waves is controlled largely by an invisible layer of charged particles, known as the ionosphere[1]. During the early days of radio communication, radio scientists were very much confused about how radio waves propagated round the globe. Both in Radio and TV communications radio wave, a form of electromagnetic waves travel in straight lines until they are deflected by some means. Earth's curvature is a direct obstruction to line-of-sight communication. When sufficient distance separates the two radio stations so that their antennas fall behind the curvature, the Earth itself blocks the transmitted signals from the receiver. There are some radio frequencies which travel in the line-of-sight. Higher the antenna of the radio transmitter, greater is the distance covered by its transmission and this makes TV transmission towers as high as possible. Radio frequencies in the range of VHF band normally propagate only in the line-of-sight. The frequencies in the range of UHF band also propagate in line-of-sight. In order to receive radio signals in these ranges at a far away place from their place of origin, we need some kind of a reflector in between. Big metallic plates on the mountain tops are passive reflectors, which reflect VHF and UHF signals to distant place. However a passive reflector is not equipped with any kind of electronic circuitry to relay the radio signal. The intention of the present work is not to produce scientific data to a large extent but rather to observe the typical noise floor conditions that a radio communication station might expect to experience. Precisely, our intention is to analyse the electromagnetic environment where large number of unknown variables are involved. It is true that without human interpretation it is extremely difficult to “drill down” into what at first sight appears to be noise, to extract the wanted signals on which successful communication largely depends.

TYPES OF COMMUNICATION CHANNELS

The communication channel is a very important part of the communication network. It is an analogue part of the system and is described in terms of the analogue quantities like bandwidth, absorption etc. It limits the bandwidth and noise power which are factors that determine the maximum information rate of the channel. Besides this the channel can introduce many kinds of distortion into the signal and causes a delay in signal propagation.

If a signal propagates through a channel of bandwidth B, the signal emerging from the end of the channel has its bandwidth reduced to the bandwidth B of the channel. Signals propagating outside the bandwidth of the channel are eleminated. The channel places a maximum value of the bandwidth of the system irrespective of the signal bandwidth. Depending on the type and length of the channel, the bandwidth is determined as shown in Figure 1(a).

Absorption : It is the term used to describe the loss of signal power in dB/m as the signal propagates through the channel. It is illustrated in Figure 1(b). Longer the channel, the higher is the absorption. Absorption is generally frequency dependent and it reduces the available bandwidth. Equalisers are frequency dependent amplifiers which can restore the spectral balance of the signal.

Attenuation : It is the fall of signal strength when it propagates along a channel and is also measured in dB/m. Repeaters are amplifiers placed along the channel to restore the signal power. The distance between the repeaters is determined in such a way that any errors in the signal due to attenuation effects is minimised, e.g. to maintain a minimum SNR along the channel as shown in Figure 1(c). A part of the attenuation affects is due to absorption. There is a loss of signal when propagates through a medium. Some typical values of media loss are shown in Table 1.

Table 1: Some typical media loss values

Transmission medium	Frequency	Loss [dB/km]
copper wire pair of diameter 0.3 cm	1 kHz	0.05
16 gauge twisted pair	10 kHz	2
	100 kHz	3
	300 kHz	6
coaxial cable	100 kHz	1
	1 MHz	2
	3 Mhz	4
fibre- optic cable	4×10^{14} Hz	5

Dispersion : It is also known as distortion as it provides the effect of different frequencies propagating at different speeds along the channel as revealed in Figure 1(d). This causes some changes in shape of the signal and is not easy to correct.Channels are occasionally limited by dispersion effect.
Propagation delay : It is the term used for describing the time taken for the signal to pass along the channel. Electromagnetic signals propagate at velocities near that of light with a typical value 2.5×10^{8} *m/s*. The propagation delay largely differs with the length of the channel.
Noise : It is the term used for describing all signals present at the receiver including those which are not part of the information signal. This is illustrated in
Figure 1(e). The source of the noise signals differs largely.
Impulse noise : It usually appears in low-frequency circuits. It originates from electric fields generated by electrical switching and appears as bursts at the receiver. The presence of impulse noise can have a catastrophic effect due to its large power. Other peoples signals can also produce noise. Cross-talk is the term given to the pick-up of radiated signals from adjacent cabling. At the time of using radio links interference from other transmitters can be problematic. Thermal noise is always present and it appears to be due to the random motion of electric charges present in all media. Thermal noise can be generated externally or internally at the receiver and may be described by the equation.

$N=kTB$ watts (1)

where the Boltzman's Constant $k=1.38 \times 10^{-23}$ J/K, T is the absolute temperature in degrees Kelvin, and B is the receiver bandwidth. The equation shows that a hot system generates more noise.

When the effects of attenutaion, absorption, dispersion, and noise are combined there may result in bit errors occuring in the transmitted signal. This is shown in Figure 2.

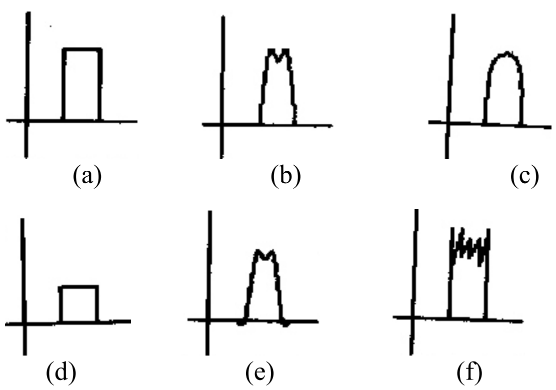

Fig. 1. (a) Uninterupted signal; effects of (b) limited bandwidth (c) channel absorption (d) signal attenuation (e) dispersion and (f) noise on a signal

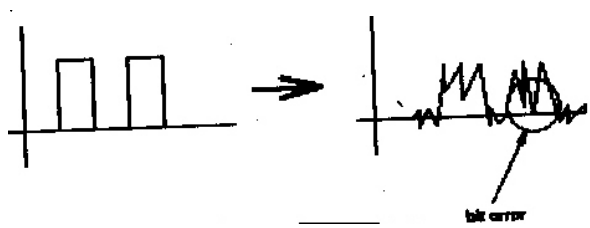
Fig. 2. A bit error is illustrated in a transmited signal due to channel effects.

Communication channels are the physical connection between correspondents. Wires, coaxial cables and optical fibres are utilized for the purpose.When the cost of cable laying become very large, it can be advantageous to use radio waves as the channel. Microwave links are high bandwidth line-of-sight links. Usually satellite links use geostationary satellites for providing inter-continental high-bandwidth communications. Optical links which transmit through free-space can be used for short, high bandwidth transmission. Radio and TV broadcasting is the natural method for communicating unselectively with large numbers of correspondents, or when one or both of the correspondents are moving. On the other hand mobile communications employ networks of radio transmitting and receiving stations.

FACTORS AFFECTING THE LOW FREQUENCY NOISE SPECTRUM

Natural noise in the lowest-frequency portion of the electromagnetic spectrum is dominated by lightning flashes all over the globe[2]. At any time an average of *2000* storms exist worldwide producing about *100* lightning strokes per second. The noise sensed at any location is influenced by the propagation path. The direct and indirect lightning-related phenomena like red sprites, blue jets etc. occurring between *30* to *90 km* height i.e. between storm cloud tops and the lower ionosphere is a significant source to ELF and VLF noise. Other sources of ELF and VLF noise include tornadoes, volcanic eruptions, dust storms, and earthquakes. The summation of signals propagating in the earth-ionosphere duct produces relatively continuous noise level that is punctuated by sferic bursts.

Out of many phenomena contributing to the noise spectrum, lightning flashes are the most dominant source[3]. A lightning discharge consists of three main parts. A series of leaders, each about a m sec in duration with a peak current of *300 amps* approximately and each leader being separated from the next one by *25* to *100 m secs* and occur over a period of about a m sec. The leaders ionize a channel for the return stroke or main discharge which lasts about *100 m sec* and has a peak current of *30 kilo amps* order. Finally there is an exponentially decaying current initially of several hundred amps with a lifetime of about *0.5 sec*. All the three parts produce radiating energy in different parts of the spectrum. The leaders being the shortest produce energy in the low frequency range above *30 kHz*. The main discharge produces a large radiating pulse with energy centered around *10 kHz*[4] .

Most of the observed lightning strokes are cloud-to-ground (CG). The leaders produce a negatively charged channel which is neutralized by the main return stroke. CG discharges being largely vertical currents, successfully couple energy to the earth-ionosphere duct and it favours vertically polarized radiation. Intra-cloud (IC) discharges are less known as they are visually masked by cloud. As the IC discharge components are mostly horizontal they are unable to couple well to the propagation medium. However, IC paths are much longer than CG paths and the vertical portion of an IC flash path is about *1/3* of its total length. Consequently about *1/3* of the total IC energy does couple to the medium and thus both IC and CG flashes contribute about the same noise energy. It means that the current-distance moments in the vertical direction are about the same[5].

Lightning storms in mid latitudes occur during the summer months, in general. So one can say that to some extent lightning activity migrates between northern and southern hemispheres semi-annually. The contributions to the total natural noise spectrum of the three lightning components are not same in magnitude and centers of lightning activity tend to migrate seasonally. All these source factors affect the temporal variability and non-uniformity of the noise spectrum up to the LF region at least.The second factor affecting the low frequency noise spectrum is the propagation medium. The D region of the ionosphere which borders the neutral atmosphere, is the layer that appears highly magnetically conductive to LF and lower frequencies. The D region is mainly a daytime phenomenon. At medium frequency the D region is an efficient attenuator due to energy absorption by ion collision and recombination. This explains why distant MF broadcast stations can be well received at night when the D region disappears and E region reflectivity becomes active. At VLF the D region is the top of a waveguide duct during daytime. The effective height of the waveguide changes with the appearance and disappearance of the D region on a diurnal basis. The lower ionosphere is a diffuse mass of neutral molecules, positive ions and free electrons that appears below the E region during daytime.

Propagation becomes further complicated by the existence of the earth’s magnetic field. The ionosphere is a birefringent medium in its presence. This birefringence causes a splitting of a wave into an ordinary ray and an extraordinary ray, and sometimes *2* extraordinary rays.This splitting of propagating wave in a magneto-ionic medium into ordinary and extraordinary components is due to the Zeeman effect,related to optics. This two waves propagates at different velocities and appear at slightly different frequency. The ordinary component behaves as if there was no magnetic field. The earth’s geomagnetic field is responsible to cause more attenuation for east-to-west paths than for west-to-east paths.

Strange phenomena like "whistlers", "tweeks", etc. are caused by dispersion in the birefringent ionosphere and magnetosphere. Interaction of propagating waves with the geomagnetic field has some added interest and exhibits interesting characters.

A study of the frequency spectra of atmospheric radio noise field strength provides information about the wave propagation, propagation of the atmospherics itself and the mecanism of lightning discharges. Watt and Maxwell [6] recorded the intensity of atmospherics at 1-100 kHz while Taylor and Jean [7] made an observation of the intensity at 1-40 kHz emitted from ground discharges. Horner [8] measured the intensity at 6 kHz and 11 MHz while Takagi [9] observed at 100 kHz-500 MHz. In MHz frequency an early observation was also taken by Schaffer and Goodall [10] at a fixed frequency of 150 MHz.In a tropical station Kalyani (lat. $22^0\ 58^/$ N, long $88^0\ 28^/$ E) which is situated at the bank of the river Hoogly and is only about 150 km away from the Bay of Bengal. We have also measured recently integrated field intensity of atmospheric radio noise at 10, 21 and 27 kHz during severe local thunderclouds.When our observed mean data are plotted over the frequency spectra of atmospherics (Fig. 3) obtained by different authors and produced by Kimpara [11], we find that there is a sharp fall of the noise level when shifted from kHz to MHz frequency band. Our observations also revealed that the characteristics of atmospherics which define their frequency spectra depend on the configuration and development of thunderclouds [12].

The noise level significantly changes according to the seasonal and meteorological conditions. The greater values of the noise level as measured over Kalyani during the cloudy months May to September compared to other months of the year, as shown in Figure 4, appear to originate mainly from disturbed meteorological conditions as experienced in the hottest months May over this area followed by severe cloud activity covering a wide area during the monsoon months June to September.

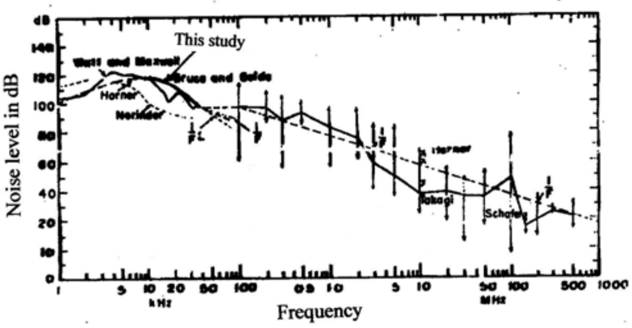

Fig. 3. Frequency spectra of atmospheric radio noise field strength from kHz to MHz band. Our observed data have been superposed over the spectra as reported by different authors measured at different parts of the globe.

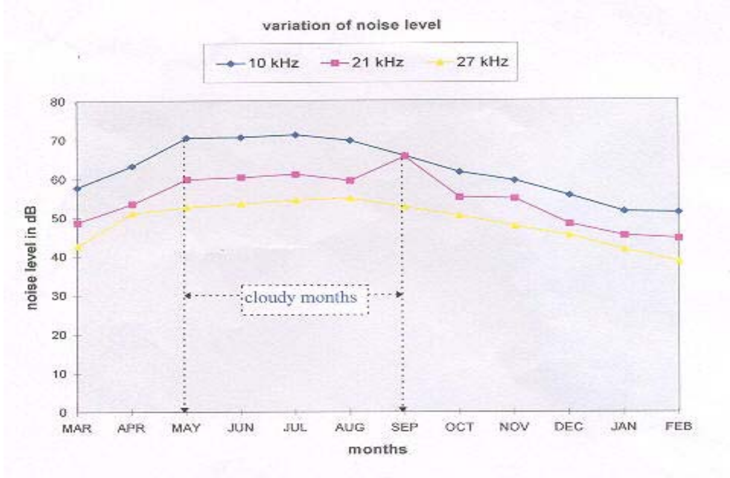

Fig. 4. Variation of the noise level at VLF band in different months of the year. The data were chosen from the round-the-clock observation of the records when there were no severe local disturbances.

The electrical activity associated with both cumulonimbus and nimbostratus clouds which are assumed to be responsible for the higher values [4] as revealed in Figure 4.

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