THE DIRECTIONAL ASPECT OF ATMOSPHERIC NOISE AND ITS IMPACT UPON HF COMMUNICATIONS SYSTEMS

C.J.Coleman

The University of Adelaide, South Ausralia, 5005, ccoleman@eleceng.adelaide.edu.au

ABSRACT

Global maps of lightning occurrence are combined with ray tracing propagation calculations to form a direction sensitive model of atmospheric noise. The model suggests a very complex directional behaviour that can strongly vary with location, time, season, sunspot number and frequency. It is shown that the directional variability of noise, when coupled with the directional variability of antenna gain, can lead to marked changes in noise outcome between different antennas. The implication of directional varying noise for the optimum choice of receiver antenna is explored.

INTRODUCTION

Most external noise is beyond the control of the radio system designer and is, as a consequence, a fundamental constraint upon system performance. The principle components of this external noise are galactic, man-made and atmospheric in origin. All of these components exhibit variations with frequency, but HF atmospheric noise can also have strong variations with respect to location, season and time. During the daytime, noise is at its lowest level with strong ionospheric absorption removing most of the non-local atmospheric component. At night, however, absorption is greatly reduced and noise levels can rise considerably. In particular, radio noise from thunderstorms (the dominant source of atmospheric noise) can propagate effectively via the ionosphere and hence make contributions on a global scale. An HF receiving system is normally designed such that the external noise environment is the only limit its sensitivity (such a system is said to be externally noise limited). As a consequence, it is important to understand the anatomy of such noise in order that its worst effects can be minimised.

The standard HF noise model is that produced by the ITU [1] and is based on observations from a limited number of stations around the world. As a consequence, it only provides a fairly coarse picture of noise distribution. Kotaki [2] has shown that model estimates of noise can be greatly improved if the atmospheric contributions are calculated from global maps of thunderstorm activity [3] by means of suitable propagation calculations. Unfortunately, like its ITU counterpart, this model does not address the directional distribution of noise and is therefore, in the strictest sense, only applicable to isotropic antennas (this issue was raised in CCIR report 322 [4]). The strongly directional nature of noise has been observed on array antennas [5]. Furthermore, on the global scale, the concentration of major thunderstorm sources over the lower latitude landmasses will cause such directional properties. Based on the thunderstorm maps of Kotaki and Katoh[3]. The author [6] has developed a noise model that is able to address the directional aspects of atmospheric noise. This model uses fairly sophisticated propagation calculations and is thus able to consider the effects of anomalous propagation (trans-equatorial propagation for example) upon noise distribution.

For the HF system designer, the importance of noise directionality is clear. The total noise entering a receiver will depend on the directional properties of the antenna and, although it might seem sensible to choose the antenna that has maximum directivity for the desired signal, it is also possible that the antenna could have a strong response in the direction significant noise sources. Signal to noise ratio (SNR) is one of the most important considerations in a communications system and it is clear that it is not simply a function of directivity in the desired signal direction. Because of this, the directional noise model of author has been developed so that it can investigate the SNR performance of an antenna for communication between specified points on the globe. Such a capability is important in planning the correct mix of antennas in an HF receiving system. The current paper will includes a brief description of the directional noise model and gives a representative example of directional noise distribution. In addition, the paper will investigates the SNR performance of a variety of antennas this representative scenario. It is demonstrated that the directionality of noise can have a significant impact upon the performance of an HF receiving system.

DIRECTIONAL NOISE MODEL

For a given receiver site, the model calculates the propagation at all elevations and to a range of 12000km. At a particular elevation θ and azimuth φ, the noise entering through a unit solid angle is calculated according to

$$N(\theta,\phi)=\sum WS\left(\frac{\lambda}{4\pi}\right)^2\frac{1}{L\sin(\psi)}$$

where W is the radiated energy of a lightning strike (about $2\times10^{-6}\,J/Hz$ at 10MHz), S is the strike rate (derived from the maps of [7]), L represents non spreading losses (absorption and reflection), ψ is the launch elevation at the lightning strike and the summation is over all sources whose radiation arrives at the receiver with the given elevation and azimuth. Figure 1 shows a typical distribution of lightning strikes looking out from Alice Springs in central Australia during an equinox evening . The resulting angular noise distribution is shown in figure 2. It will be noted that there is a concentration of lightning sources over South East Asia (to the north west at a range of around 4000km) and these result in a concentration of noise arising from the north west.

IMPACT UPON HF SYSTEM DESIGN

An important issue in the design of an HF communications system is the choice of antenna. This must have substantial gain in the direction from which the desired propagation arrives (figure 3 shows that the elevation at which a signal arrives can vary markedly with source range). Figure 4 shows the gain patterns of 3 typical HF communications antennas. These are a biconical monopole (BICONE), a horizontal travelling wave dipole (TWD) and a horizontal log periodic antenna (HLPDA). Conventional wisdom would normally choose the antenna which has the greatest gain in the direction of the propagation from the desired range. For ranges between 1000km and 2000km, this would suggest the monopole or log periodic be chosen in preference to the dipole. Figures 5, 6 and 7 show the simulated SNR (signal to noise ratio) for the various antennas and from which it will be noted that the performance of the dipole is superior to that of the monopole for ranges from 1000km to 2000km. Furthermore, the improvement provided by the log periodic is well below that which would be expected on the basis of gain alone. Since the major noise contribution arrives at low elevations, and the dipole has much poorer low elevation response than either the log periodic or the monopole, it is clear that dipole collects much less noise and this is responsible the anomalous SNR behaviour. As expected, the performance of the dipole is superior for the shorter ranges, but that this superiority is further enhanced by the reduced noise response. In conclusion, it is clear that proper attention needs to be paid to the directional properties of noise if an HF communications system is to exhibit optimal performance.

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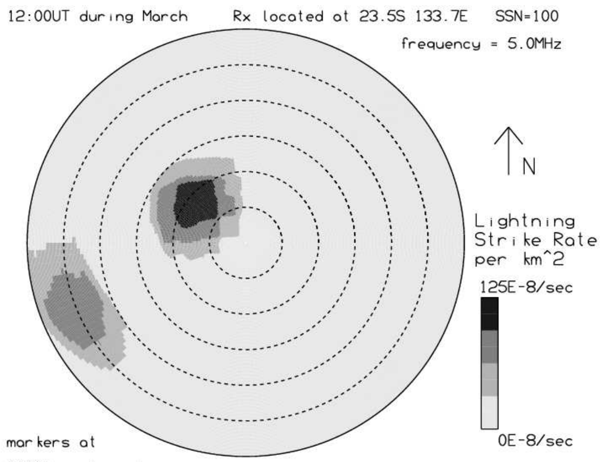

Fig.1. The distribution of lightning strikes as a function of distance from receiver.

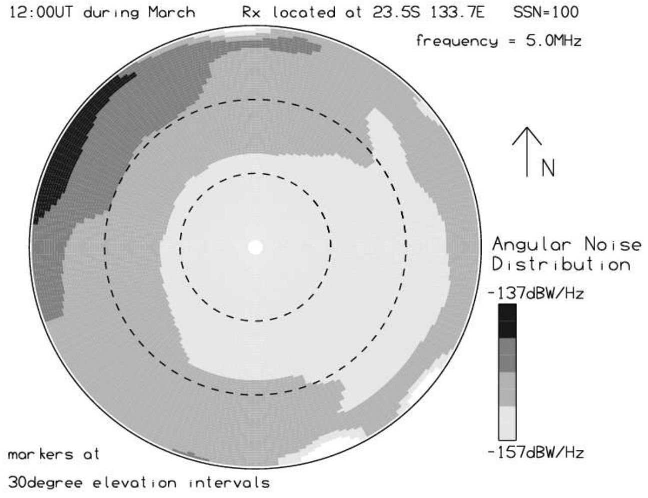

Fig. 2. The distribution of received noise as a function of elevation and azimuth.

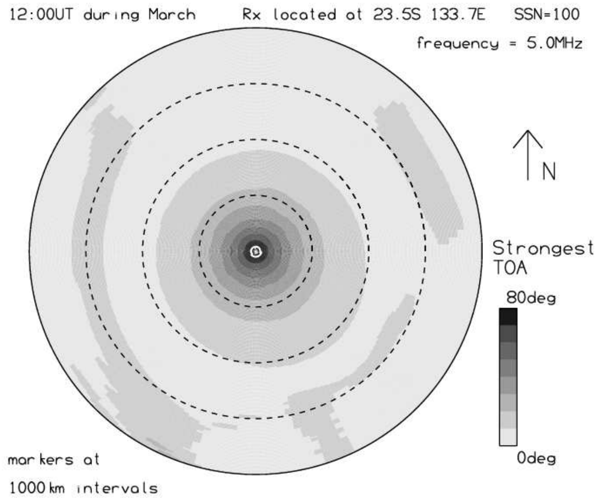

Fig. 3. Elevations at which various propagation enters the antenna.

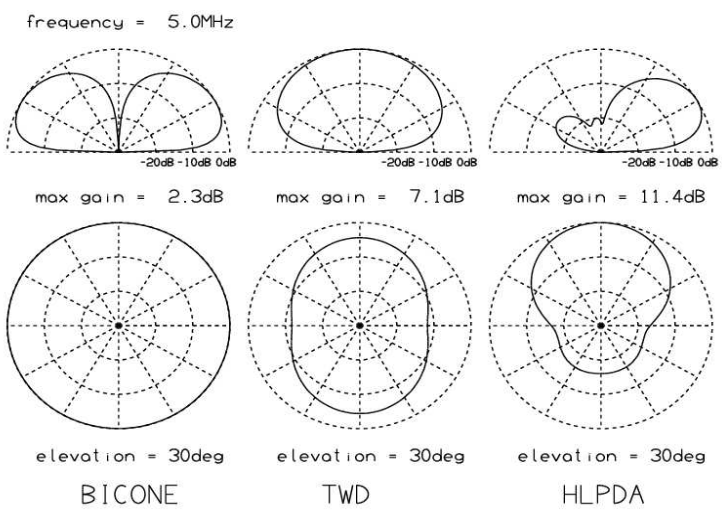

Fig. 4. Representative cuts through the gain patterns of some important HF communication antennas.

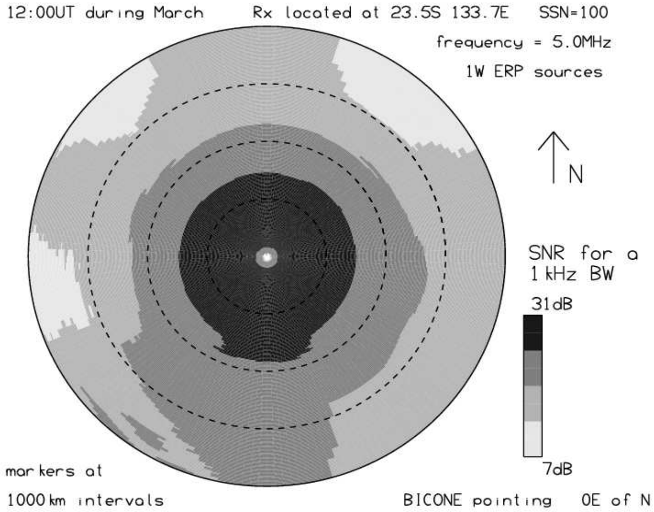

Fig. 5. SNR at the receiver as a function of range for a biconical monopole antenna and 1KW ERP source.

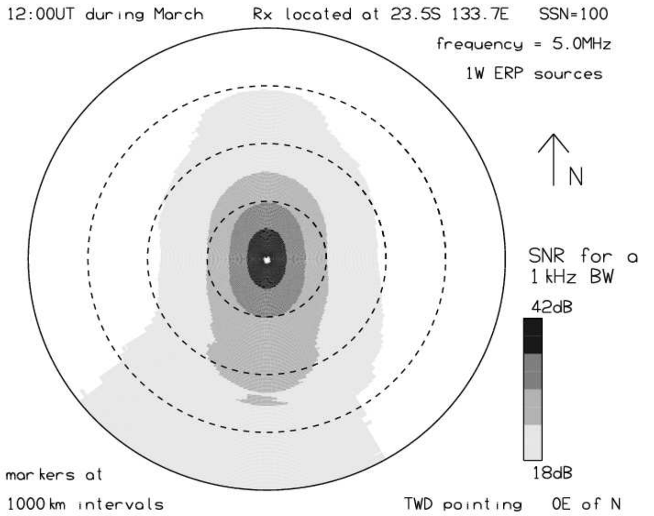

Fig. 6. SNR at the receiver as a function of range for a travelling wave dipole antenna and 1KW ERP source.

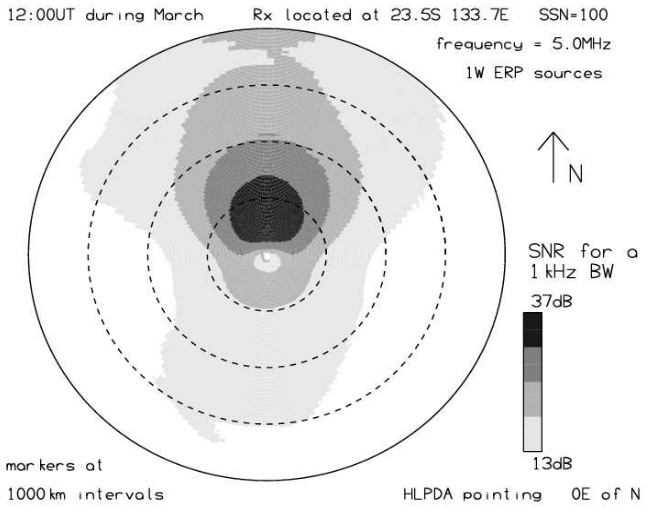

Fig. 7. SNR at the receiver as a function of range for a horizontal log periodic antenna and 1KW ERP source.