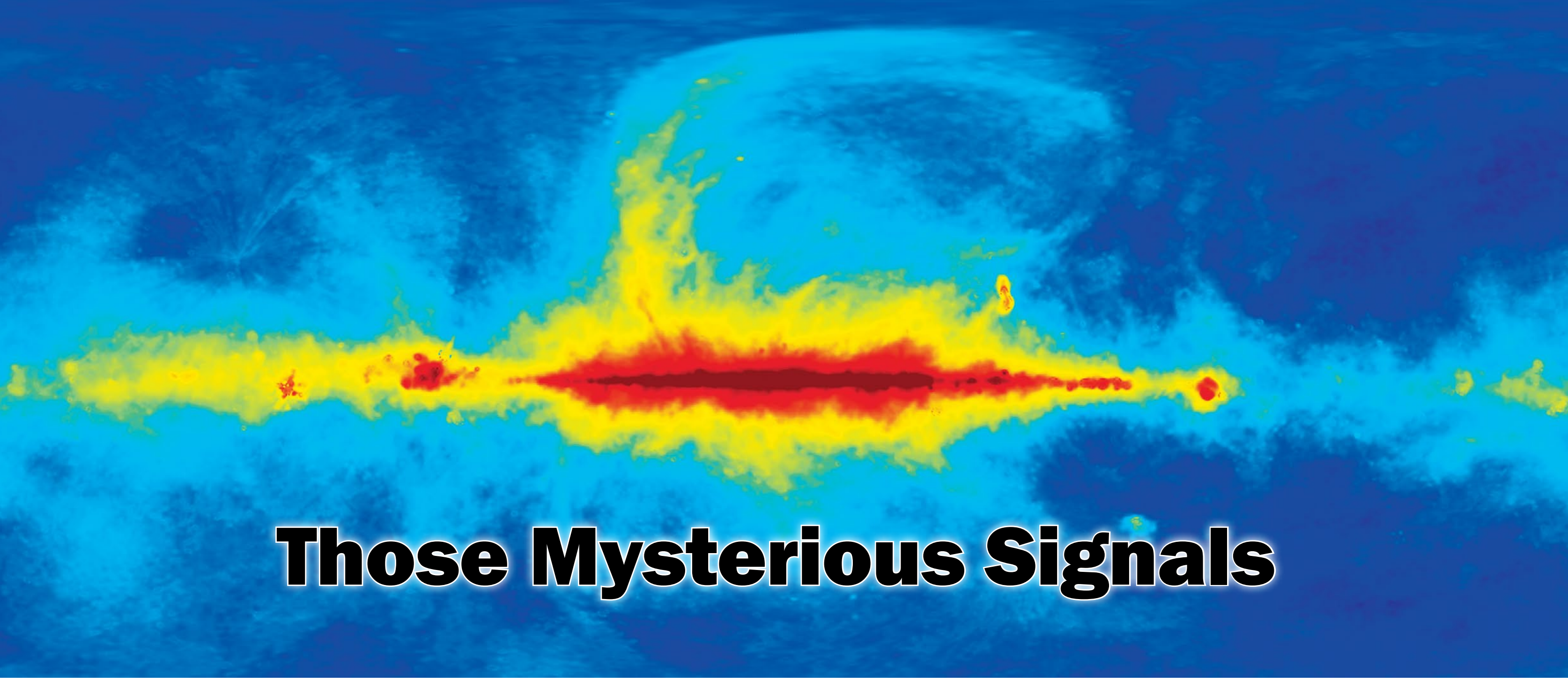

Those Mysterious Signals

Courtesy NASA's Data Center for Cosmic Microwave Background Research

They may sound like noise to us, but to radio astronomers they are the desired signals.

Arch Doty, W7ACD

Every Amateur Radio operator who uses the high frequency (HF) bands has noticed that there is a low level of "signals" present, 24 hours a day on all of those bands, even though the bands may be devoid of man-made signals.

Depending on frequency, these mysterious signals may come from one of two entirely different sources, and are propagated by one of two entirely different modes.

Cosmic Noise — What Is It and Where Does It Come From?

Cosmic noise is broadband electromagnetic radiation that emanates from many different sources. At HF, Cygnus A and Cassiopeia A are major sources of cosmic noise.[1] Lower level signals come from quasars, pulsars and other remote objects. A comprehensive discussion of these sources is beyond the scope of this short article. The Internet will provide a wealth of references to documents that can be read by anyone interested in obtaining in-depth information.

Most amateurs view cosmic noise as a complex type of electromagnetic radiation studied by scientists with the aid of monstrous rotatable parabolic dish antennas such as those at Green Bank in West Virginia, Jodrell Bank in England and a few other similar sites around the world.

[1]Notes appear on page 39.

The truth is quite different: Every amateur who operates on the HF bands can hear cosmic noise at any time of the day or night by listening on frequencies not drowned out by amateur signals or atmospheric noise.

Cosmic noise is certainly the ultimate DX! Receiving a QSL card, however, might be a bit of a problem. The strongest noise that you will hear on 10 meters, for example, will often be from the galactic center of the Milky Way, and was created about 27,000 years ago. Then there is the "late arrival" cosmic noise from Cygnus A, which started its journey to you 760 million years ago. (These interesting facts courtesy of Darrel Emerson, AA7FV.)

Cosmic Noise Signal Levels

A summary of the level of broadband radio noise that may be expected in typical receiving environments is contained in the International Telecommunication Recommendation ITU-R P.372.[2] A copy of Illustration 2 from that recommendation is shown as Figure 1. On this graph the signal strength of cosmic noise (D) and atmospheric noise (between A and B) are plotted against frequency.

In viewing this figure, and the following description of the tests that I have conducted, it must be remembered that it is hard to determine the precise frequency at which the signal strengths of cosmic and atmospheric noise cross over because that frequency will depend on the time of day, whether the galactic center is above or below the horizon, the state of the ionosphere and a host of other factors.

What's the Real Story?

As I wanted to obtain more precise data than can be obtained from the ITU illustration, I decided to make measurements of my own. The main problem facing anyone wishing to measure the strength of cosmic noise is differentiating it from the atmospheric noise that is discussed later in this article. They both sound the same and look the same on a computer screen. The answer to this problem is the arrival direction of the signals. As also discussed later in this article, during the two years that I have been making measurements, cosmic noise has arrived predominantly from the northern quadrant, while atmospheric noise came from the south.

Thus, in my test series, I measured the radiation received from the northeast (where cosmic radiation was arriving from when I performed the tests) and from the south-southeast (arrival direction for atmospheric noise) on 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 25, 35 and 40 MHz. I determined that the predominant low level background signals received above 15 MHz, including those on the 6, 10, 12, 15 and 17 meter bands, were from cosmic sources.

For the reasons enumerated above, the relative level of cosmic noise may vary considerably over time. On several occasions after these original tests were conducted,

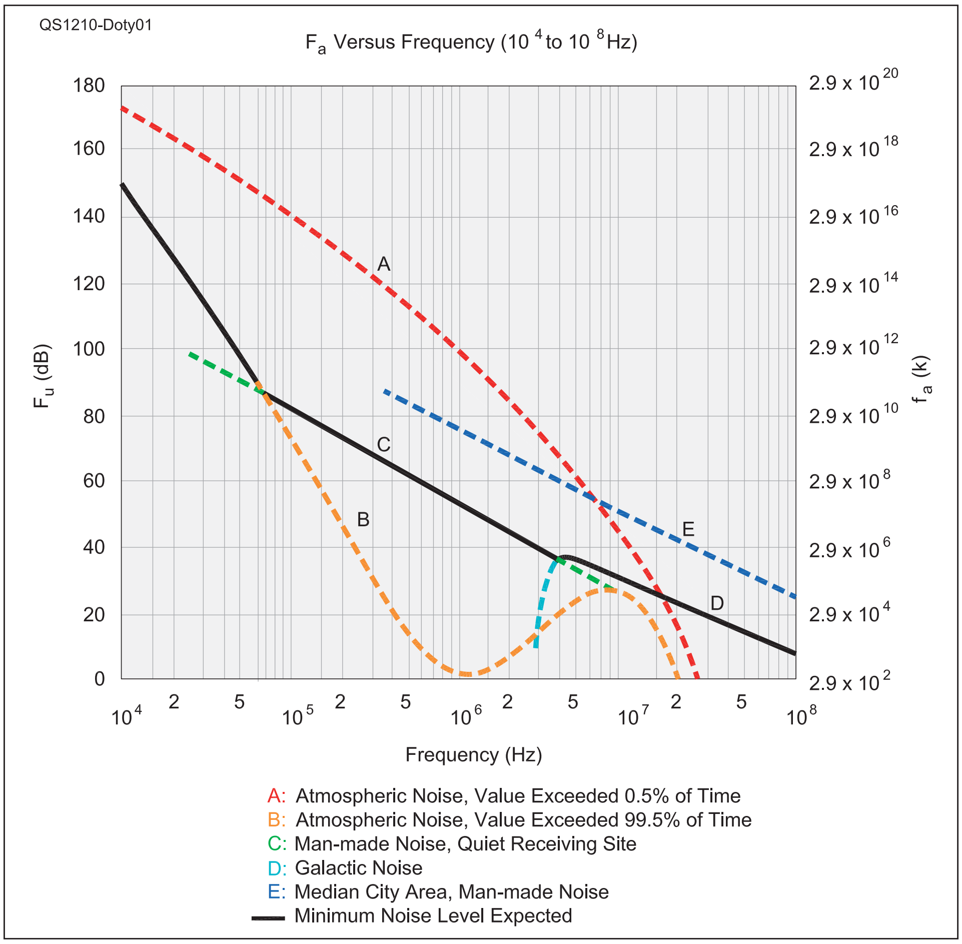

Figure 1 — Signal strength of cosmic noise (D) and atmospheric noise (A) plotted against frequency. From ITU Recommendation ITU-R P.372.

there were times when cosmic noise was dominant on 20 meters.

My next objective was to determine the difference between daytime and nighttime signal strength levels of cosmic noise.

Table 1 shows what was recorded on 28.6 MHz. Incidentally, the readings taken from midnight to 6 AM were no problem. People of my age are often up at regular intervals during the night — even if not primarily for the purpose of taking signal strength readings.

Table 1
Recorded Noise Strength Level (dB below S-9) at Different Times of the Day

Time (PDT)	Noise Strength	Time (PDT)	Noise Strength
1700	–8.0	0200	–8.4
1800	–7.9	0300	–8.5
1900	–8.0	0400	–8.5
1941	Sunset	0500	–8.4
2000	–7.9	0600	–8.0
2100	–7.0	0638	Sunrise
2200	–7.0	0700	–8.0
2300	–8.4	0800	–8.2
2400	–8.6	0900	–8.8
0100	–8.5	1000	–8.8

How is Cosmic Noise Propagated?

Cosmic noise is received on Earth directly from the cosmos. It is thus subject to discontinuities resulting from its passage through the Earth's ionosphere and atmosphere. As cosmic noise is of a relatively low level it is commonly hidden by communications signals, and atmospheric noise from local or distant sources. At times of poor ionospheric HF propagation on the higher frequency bands, the less dense ionosphere allows cosmic noise to pass through with less attenuation.

What Direction Does Cosmic Noise Arrive From?

Cosmic noise originates, as described above, from a wide area of our galaxy and beyond. As a matter of curiosity I made 10 tests from August 2010 to January 2011 to learn the direction from which cosmic noise arrives at my Oregon location. In these tests the signal strength of atmospheric noise was measured as my three element beam antenna at the top of a 75 foot tower was rotated 360°. All of the tests were made at approximately the same time of day.

All 10 of those tests showed that the maximum strength of cosmic noise arrived from between north and northwest. In all of the tests there was zero signal coming from southern directions. [If you try this, you may find that your noise readings peak more to the south. In most areas the maximum upper HF and VHF cosmic noise will be from our Galaxy, the Milky Way, and the peak will be in the direction of the southern constellation Sagittarius from your location. — *Ed.*]

At other locations, at different seasons, or at a different time of the day, however, the arrival direction of cosmic noise may vary considerably because the Earth rotates but the sources of cosmic noise do not.

Atmospheric Noise — What Is It, and Where Does It Come From?

As noted in an earlier *QEX* article, "atmospheric noise is the result of the very broadband electromagnetic impulses that are caused, primarily, by the 100 lightning flashes that occur every second somewhere in the world."[3] These impulses (sometimes called *sferics*, or *spherics*) may propagate for thousands of miles in whatever fashion desired signals on the same frequency would propagate. VLF and LF signal components from the lightning source will propagate without major attenuation in the Earth-Ionosphere waveguide.

Antennas operate by intercepting electromagnetic waves (including those created by lightning) and converting them into electrical current for the receiver to amplify and detect. Thus there is a direct correlation between atmospheric noise levels and the signal strengths indicated by a communications receiver.

Atmospheric noise may thus be visualized as bursts of radio waves transmitted by 100 multimegawatt radio stations each second. The thunderstorms that produce lightning are truly awesome. The energy released by a typical thunderstorm is in the same order of magnitude as that which was released by early atomic bombs. A substantial amount of this energy is released as broadband electromagnetic waves — the same type of radiation as used by amateurs for communication.

The chart in Figure 2 shows where lightning is occurring around the world. This data may be accessed in real time on the Internet by searching for "TOGA Lightning" and then select "TOGA Network Global Lightning Maps."[4] These maps clearly show that the

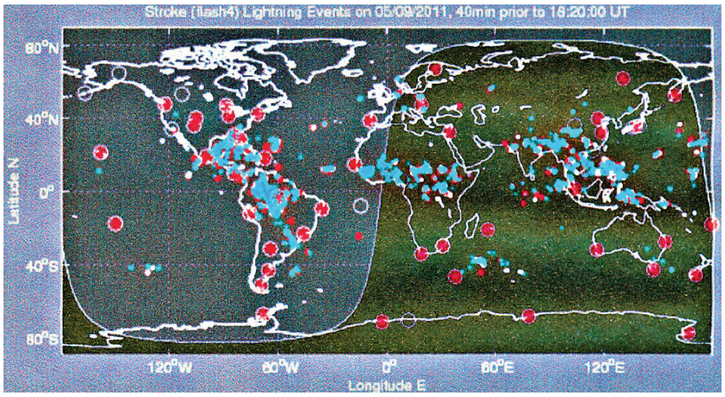

Figure 2 — Where lightning is occurring around the world. Blue indicates the most recent lightning strikes while green indicates earlier strikes and yellow, even earlier strikes. Red indicates the oldest strikes, those from 30 to 40 minutes earlier.

vast majority of global lightning discharges are in the tropical region, which is, of course, south of Oregon.

Earlier in this article, I mentioned the series of tests that I conducted to determine the relative levels of cosmic and atmospheric noise at a series of frequencies between 9 and 40 MHz. The results were that the predominant low-level background signals received below 15 MHz, including those on the 20, 30, 40, 80 and 160 meter amateur bands, were atmospheric noise. As discussed earlier, the relative signal levels of atmospheric and cosmic noise vary over time for many reasons. Thus I have noted times when cosmic noise dominated on 20 meters.

How is Atmospheric Noise Propagated?

More than half a century ago, during WW2, I was piloting a four engine transport from India to China over the Himalayan “Hump” route.[6] Although we were hundreds of miles from any radio station, an S-9 signal suddenly activated my radio, and I found myself talking to the airport tower operator in Nome, Alaska — on approximately 135 MHz. This is a frequency that normally provides only a few miles of line-of-sight communications. After I convinced the operator that I really did not want landing instructions, we had a nice chat for several minutes. He was a ham, incidentally, but he never sent a QSL card for our contact.

Atmospheric noise is propagated worldwide — via whatever propagation modes support the frequency components. Some may propagate through ducting, or more likely sporadic E layer propagation as supported my VHF signal to allow me to contact Alaska from high above the Himalayas. Electromagnetic ducting is still the subject of scrutiny by scientists. For the purpose of this article it may be visualized as a waveguide having the earth as its bottom element and the cloud of electrons that constitutes the ionosphere as the upper element.

What Direction Does Atmospheric Noise Arrive From?

As shown above, the thunderstorms that generate atmospheric noise are, to a major extent, located in the tropical region of the world. The propagation processes that carry atmospheric noise signals around the world are affected by many factors, however, just as they affect our desired signals.

There are a great number of references in the literature to estimates of what the signal level of atmospheric noise might be at various global locations and at different frequencies. All of these estimates depend on exotic models and formulas that are far from comprehensible by most people. During the 2 years that I have been investigating cosmic and atmospheric noise, the atmospheric noise signals have always arrived from a southerly direction.

Methodology

The data presented above was obtained using a specially calibrated ICOM IC-756 PRO 3 receiver augmented by a Ramsey RF broadband preamplifier, when necessary.

In Closing

This article is, as far as I can tell, the first comprehensive description of cosmic and atmospheric noise that has appeared in an Amateur Radio publication, and it certainly leaves many questions unanswered. I hope that this article will be of sufficient interest to encourage further investigation by radio amateurs into the composition and transmission of cosmic and atmospheric noise, and that they will be able to add to the current paucity of knowledge of these interesting types of electromagnetic radiation.

This article could not have been written without the greatly appreciated assistance of Darrel Emerson, AA7FV/G3SYS.[6] Dr Emerson was the only reader who questioned the reference, in my recent *QEX* article, to “atmospheric noise.”[7] His question lead to the new series of tests referred to above that showed that this reference is correct when applied to frequencies below 15 MHz, but not to the higher frequencies that were discussed in that article. An appreciable amount of the information on cosmic noise presented in this article was either provided by Darrel, or was obtained from the references that he supplied.

In my view, his two part *QST* article provides the most comprehensive data on radio astronomy that has ever been published in an Amateur Radio publication.[8] Darrel’s expertise in radio astronomy is exceeded only by his kindness to his fellow Amateur Radio operators.

Sincere thanks also to Bill Conwell, K2PO, for providing additional references, advice and editing of this article. The help of Dr Howard Diamond, Director of the World Data Center for Meteorology at NOAA’s Climatic Data Center was very useful.

Notes

[1]**www.nasa.gov/milky way**

[2]International Telecommunication Union Recommendation ITU-R P.372 (Radio Noise), ITU, Geneva, Switzerland, 2009.

[3]A. Doty Jr, W7ACD, “The Effect of Ground Conductivity on Antenna Radials,” *QEX*, Mar/Apr 2011, pp 15-18.

[4]“Lightning Activity for Earth,” **wwllb.net/toga-networks-global-maps.htm**.

[5]A. C. Doty Jr, W7ACD, *The Diary of a Pilot*, Booklocker Press, 2007. (Available at **www.amazon.com**.)

[6]Private e-mail communications, D. Emerson to A. Doty, Sep 16 to Oct 4, 2011.

[7]A. Doty, Jr, W7ACD, “The Effect of Soil Properties on the Performance of Antenna Radials,” *QEX*, Sep/Oct 2011, pp 8-13.

[8]D. Emerson, AA7FV, G3SYS, “The Radio Sky,” Part 1, *QST*, Jun 1996, pp 32-35; Part 2, *QST*, Jul 1996, pp 28-31.

Arch Doty, W7ACD, holds an Amateur Extra class license and is a Life Member of the ARRL and a member of its Diamond Club. He is a former Director of the Radio Club of America, the Quarter Century Wireless Association and the US Marconi Foundation. He is a Senior Life Member of the IEEE, and has been a member of the Institute’s Antenna and Propagation Society for more than 40 years. He has also been a member of the SAE Electromagnetic Compatibility Committee for over 50 years. Arch has worked more than 100 countries on 160 meter phone and thinks that he has probably spent more hours on that band listening to atmospheric noise than to amateur signals!

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