The Background Noise on the HF Amateur Bands

Introduction

The intention of this leaflet is to give a brief overview of the HF background radio noise as it concerns the radio amateur. Detailed studies into noise levels at various locations have been undertaken by organisations such as RSGB and VERON; anyone wanting more information should follow up these. Everyone is familiar with the term "noise", but that very familiarity means it is difficult to tie down exactly what it means. It often means different things in different circumstances. In this leaflet "noise" means broadband radio interference either natural or man-made. In the UK it is often simply referred to as Radio Frequency Interference (RFI) and this convention is followed in this leaflet.

The HF Radio Noise Environment

On HF (3 - 30 MHz) there will always be noise picked up by the antenna, however well it is sited - this is called the ambient radio noise. This noise may be either man-made or natural, and unless the receiving antenna is extremely inefficient, will be much greater than the thermal noise generated in the front-end of the receiver. As frequencies rise into the VHF region, the natural noise decreases, until above about 100MHz the thermal noise in the receiver front-end becomes significant.

Natural Noise

This is the 'bottom line' of the noise in any particular location. It comes mainly from noise from atmospheric discharges which are always taking place somewhere in the world and are propagated by the ionosphere. There is also the noise coming from space usually called galactic or cosmic noise. Both these sources sound like white noise

There may also be local atmospheric static but this is usually not a serious problem in the UK. In residential and urban locations the natural noise will be lower than the man-made noise and not directly observable.

The ambient noise floor

Traditionally the ambient noise floor has been defined as the noise which exists when specific local sources of noise (sometimes called 'incidental noise') have been eliminated. If the ambient noise is observed on a horizontal dipole antenna situated in a garden in a residential area, a 'floor' will be seen consisting of the natural noise, plus an aggregate of distant man-made sources. This is usually fairly constant in any particular location and sounds like white noise with an added gritty component. While this is still a useful concept, the practical application has been confused by the growing number of 24/7 broadband RFI sources in residential locations.

The term 'noise floor' is sometimes used to refer to the ambient noise in general, so care is needed in interpreting statements on noise. This is usually just fortuitous, though attempts have been made to justify broadband interference by claiming that it simply "raises the noise floor" and so does not count as interference. Needless to say, such suggestions get short shrift from organisations representing radio interests.

Man-made noise

Sources of man-made noise, in a typical residential location, tend to fall into two broad categories. Firstly, there are the traditional sources such as motors and other sparking devices. Sometimes these can cause quite high levels of interference but in most cases they are in use for only a limited time.

The other category is interference from digital electronic equipment, particularly the ubiquitous switch-mode power supply (SMPU). All such devices are 'unintentional emitters'. In most cases units that are compliant with the relevant EMC Standard will not be a problem unless they are very close to the receiving antenna or for some reason are being misused. A lot of reported cases of noise from domestic devices are from rogue devices where EMC regulations have simply been ignored. Apart from the local domestic sources noise from power generation and transmission systems such as solar panels, wind farms and wireless charging installations have become a cause of concern. In this case the potential threat is enhanced by commercial and political pressures.

In recent years a new class of digital RF noise sources has become important. This is where RF energy is deliberately generated for the transmission of data down cables intended for other uses and where radio communication is not intended, such as telephone or electricity services. These are also classed as unintentional emitters. With such systems it is possible to manage the frequency spectrum of the RFI to avoid certain frequency bands (notching). The most prominent example of this notching is the in-house Powerline Adaptors used to link computers and to distribute video signals. This is sometimes called 'managed interference".

Assessing the Noise

Objective

Apart from general interest, the main reason for assessing the noise at an amateur station is to determine whether the noise is more or less than what might be expected, or whether there is an abnormally high noise level which warrants investigation and action to reduce its impact.

The antenna

The essential requirement for any noise investigation is an antenna sensitive enough to enable the background noise to be observed at least 6dB above the preamplifier / receiver noise. Any amateur antenna will usually do this in its intended bands of operation, but it will be easier to interpret observations if a simple antenna is sited as far from the house as possible. The best antenna to use for this sort of work is a horizontal half-wave dipole at a height of 8m or more. An inverted Vee is a simple alternative and has the benefit of being easy to improvise for a temporary setup.

At frequencies below 10MHz a half-wave dipole may not be practical. A doublet fed with open wire feeder or 300 ohm ribbon can be used. A dipole is sensitive enough, but has the disadvantage of being narrow band so that it can only cover one amateur band. A further advantage of the dipole is that a quick confidence check can be made by measuring the VSWR and making a few contacts.

If an active antenna is used the noise from the antenna amplifier should be at least 6dB below the expected ambient noise floor level.

Using an Available Receiver (Transceiver)

Is there is a local source of RFI which needs investigation or is the noise what might be expected for that location? To answer this, see if you can observe the background noise floor or whether it is permanently obscured by local broadband interference. In a nutshell, the noise floor is the best you are going to get, but if you are suffering local, broadband interference, then it may be worth taking steps to improve matters.

Start by listening across the band with the receiver set to AM or SSB, ignoring wanted signals and short periods of local noise. After this, leave the receiver tuned to a frequency which is as clear as possible of off-air signals and just listen to the activity. On some receivers clearer results may be obtained by switching off the AGC and using the RF and AF gain controls to set the required conditions.

At least some of the time the noise should be the typical background noise, “white” sounding but with small fluctuations, occasional clicks and a slight “graininess”. This will be the background noise floor. If you cannot observe this, even after long periods of listening then there may be a source of continuous broadband interference nearby. Usually local sources of noise such as switch mode PSUs (SMPSUs) have characteristic sounds easily distinguished from the noise floor.

If what appears to be the background noise floor is “smoother” than might be expected but the S meter reading is higher than expected then there may be a local source of “quasi white” noise interference. VDSL is the most likely cause. See Leaflet EMC 15. EMC Leaflet 15 VDSL Interference to HF Radio.

Using a Measuring Receiver

If a measuring receiver is available a much better assessment is possible and comparison can be made to published information such as ITU-R P.372. There are a large number of variables to take into account such as bandwidth, antenna type, detector type so that any comparison can only be approximate.

The receiver must have a sensitivity comparable to a communications receiver so that receiver noise is well below the noise being measured. Modern measuring receivers are very sophisticated and have a price tag to match, but for the present purpose an old measuring receiver from the pre-digital era will be perfectly adequate. These can sometimes be found at rallies or on the web at modest cost.

Set the receiver to the type of detector required. This could be average, rms, peak or quasi-peak. Set the bandwidth to 9kHz. (Some vintage measuring receivers have only quasi peak detectors and a fixed 9kHz bandwidth). Tune round the band as described above and then leave the receiver tuned to frequency where there are minimum off-air signals. Adjust the attenuator and listen while watching the level indicator to see if the noise floor can be observed. This should be fairly constant over time fluctuating a dB or so around an average figure. In a crowded band it might be easier to use a narrower bandwidth and make the necessary correction to the results. If very narrow bandwidth is used bear in mind that the noise being measured is not truly white and conversion may be problematic.

Using an SDR Receiver

Software Defined Radio (SDR) receivers which work with an appropriate PC application are widely available.

These give an excellent view of what is happening on the spectrum or waterfall but should be used with caution in noise investigations. In particular the resolution bandwidth of the wide band spectral display can be set very narrow and if the appropriate averaging is not set the true background level will be masked by swift variations in the signal readings. Most SDR's have a second spectrum scope which shows the digital down converted portion of the full spectrum, analogous to IF in a conventional receiver. They then allow many variations of demodulation bandwidth and mode to be selected which can be very helpful in identifying the signature of quasi-white noise on the demodulated spectrum display. Some SDRs have an amplitude display scaled in dBm or in dBµV; but it is wise to check calibration against a known source. Comparison to expected field strength is only possible if the antenna factor of the antenna in use is known.

Where to look for information on radio noise

International studies of noise on HF go back to the 1950s when CCIR published Report 322 on atmospheric noise and produced Recommendation PI.372. In 1993 CCIR became ITU-R and the information from 322 was incorporated into Recommendation ITU-R PI.372. The current issue, ITU-R P.372-13, is available, free of charge, on the ITU web site.

In P.372, HF man-made noise levels are rms, median values, quoted as if measured on *lossless monopole antennas* – monopoles over a perfect ground plane. Man-made noise levels are divided into four categories. *business*, *residential*, *rural* and *quiet rural*. It is interesting to note that there is a surprisingly large difference between rural and quiet rural, which has led to speculation as to how the criteria were selected. These noise levels are only useful in giving a general idea of what might be expected. It is not a question of measurement accuracy but the fact that the conditions of measurement and the environment will differ widely. The levels from ITU-R P.372-13 are shown in Figure 1. RSGB EMCC have also made a number of measurements in Rural and Quiet Rural locations away from man-made sources using tuned loops or horizontal dipole antennas. These points are also plotted in Figure 1.

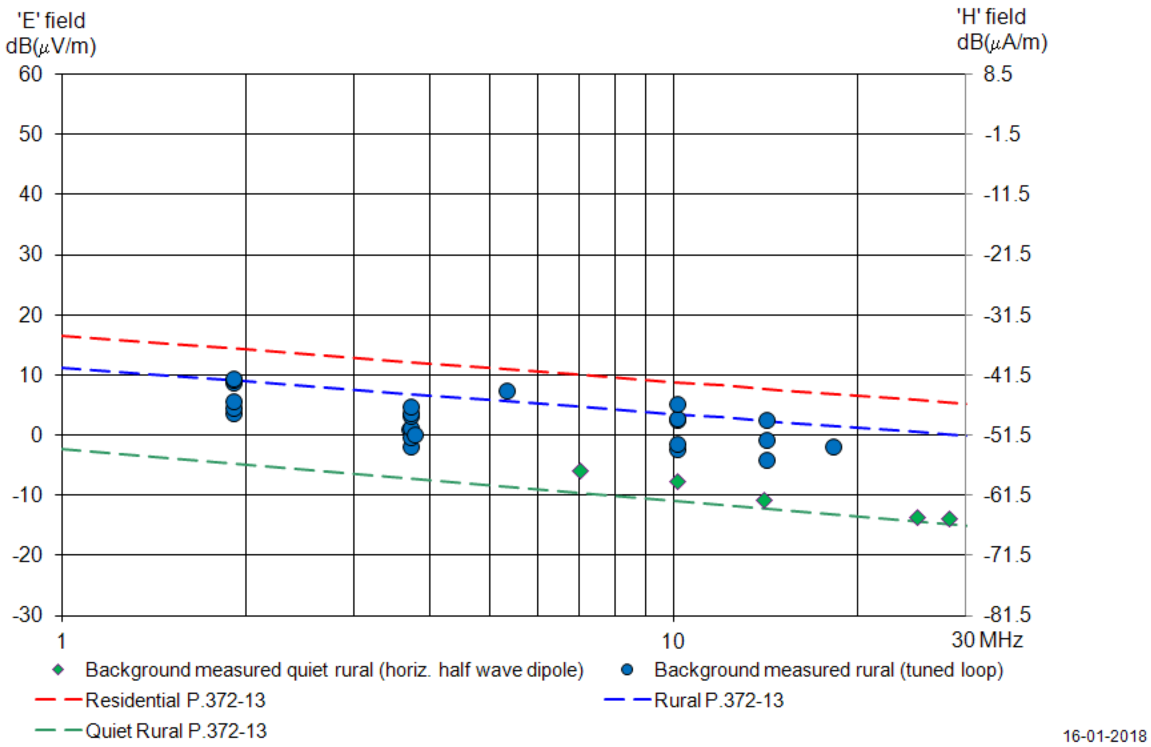

Figure 1 ITU/R P.372-13 expected receiver noise levels together with levels measured by RSGB EMCC 2014 to 2017.

The curves from ITU-R P.372-13 Fig 10 have been converted to E-field in dB(uV/m) using Equation 7 in P.372-13.

It has been suggested that in the middle of the HF band an amateur station in a residential area might expect something between *residential* and *rural* based on the P.372 criteria. The RSGB has been running a noise measurement campaign since 2013. Interim results are available on the RSGB web site under "Propagation" and a final report can be found in January 2018 edition of RadCom page 86. Veron has been involved in noise measurements for several years and information can be found [Results of Measurement Campaign.pdf]

S Meters

S meters have the reputation of being notoriously inaccurate. Older receivers with simple S meters working directly off the agc did not indicate low level signals**.** Signals would be quite large before the needle stirred off zero. Modern receivers are better in this respect. Many have built-in pre-amplifiers which are automatically switched in or out for the different amateur bands but which can be manually selected if desired. S meters can be useful in noise investigations but it is important to remember that S meters are calibrated using a signal generator whereas the noise is broadband. This means that the indicated level will depend on the receiver bandwidth.

IARU Region 1 recommendation R1 defined the calibration for S meters as 50µV in 50ohms. This made S9 -73dBm. Each S point is 6dB so that S1 is -121dBm or 0.21µV.

Antennas and noise

Generally, a good transmitting antenna will also be a good receiving antenna, but on HF the requirements for receiving and transmitting antennas are not always the same. Since, at these frequencies, the ambient noise sets a limit to small-signal reception it may be better to mount a relatively poor antenna in a low noise location than to have an efficient antenna mounted where the man-made noise is high.

In normal amateur HF operating, signals arrive by ionospheric propagation and will be a mixture of vertical and horizontal polarisation. With this in mind it is worth looking at two basic antennas from the point of view of optimising the ratio between signal and ambient noise.

The dipole. The horizontal half wave dipole has always been a popular antenna. Apart from its simplicity and low cost it is has the advantage of receiving primarily horizontally polarised signals (except off the ends) so that it is insensitive to vertically polarised noise. In practice the inverted Vee half-wave dipole gives pretty much the same results.

The vertical antenna tuned to resonance on one or more amateur bands. These are popular because they are convenient and unobtrusive. Verticals have a reputation of picking up more noise than a horizontal dipole and this seems to be deserved. They are sensitive to vertically polarised noise and in particular they will respond to surface-wave noise.

The small tuned loop antenna for reception. Receiving tuned loops are often used where a small but sensitive antenna is needed for interference investigations. It is possible to make a small tuned loop feeding directly into a well balanced high impedance amplifier providing gain and also transforming the high impedance to 50 ohms. The sensitivity is remarkably good and it should be possible to "see" the noise floor in a residential location. The disadvantage is that such a loop has a high Q factor and consequently a narrow bandwidth. Professional portable tuned loops are sometimes used for radio interference investigations. These should not be confused with the broadband loops which are used for EMC measurements where relatively large signals are involved. These are very "deaf" in radio terms.

Caution is needed in interpreting noise levels measured on loops. The relationship between E and H noise fields will be different in different electromagnetic environments.