Identifying and Locating Short-Duration Interferers

White Paper

The ability to efficiently detect, analyze and locate sources of radio-frequency interference has become increasingly important in modern wireless networks. Unlike constant or near-constant sources, so-called short-duration interferers can only be detected for brief periods of time and therefore special tools and techniques are often required when searching for these types of signals. This paper discusses the causes and characteristics of short-duration interferers and the most effective methodologies for resolving them in an effective and timely manner.

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White Paper

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1 INTRODUCTION

The term ‘interference hunting’ is used to describe the process by which an interfering signal is identified and located. Wireless devices and services represent a critical component in the infrastructure of our modern society, and the importance of rapid and efficient mitigation of RF interference issues has likewise taken on an increasingly important role. In addition, performance improvements in modern networks also requires a ‘cleaner’ RF environment than older technologies, meaning that lower-level and shorter-duration signals now make up a substantial percentage of interference issues in both commercial and public spectrum. Fortunately, advances in wireless communication technology have also been accompanied by advances in the tools and techniques used to locate these types of interferers. The most important of these advances have been in the area of increased speed, both of the instruments themselves and in systems using these types of instruments. The importance of instrument speed becomes even more apparent when we examine the types of signals, especially so-called “short duration” signals, most commonly encountered during interference hunting.

Generally speaking, most interference hunting consists of three phases: identifying the interfering signal, obtaining a rough location fix, and obtaining a final location fix. In the first phase, we are often driving an affected area in the hopes of detecting the interfering signal. In this case, speed is highly important in that we do not want to miss the signal and we do not want to have to drive at an unusually low speed or repeat our drive routes. The higher the probability of intercept (POI), the more likely we are to see the interfering signal the first time.

The second phase begins when we have more specific information regarding the target signal, namely, the frequency (range) and the spectral ‘shape’ of the interferer. Armed with this information, the goal then becomes to obtain a rough (~100 meter) fix as quickly as possible. This can be done in a variety of ways, although most commonly some form of direction finding (either manual or automatic) will be used.

The third and final phase typically requires the interference hunter to proceed on foot, searching for the precise source (physical device) that is responsible for generating the interfering signal. In this phase, the area is most often ‘scanned’ or ‘swept’ with a handheld directional antenna.

2 SHORT DURATION INTERFERERS

For the purpose of this paper, interference sources can be grouped into two rough categories : constant / long-duration interferers and short duration interferers. A 'constant' interferer is one that is transmitting without interruption (one with an 'on-time' or 'duty cycle' of 100%). A 'long-duration' interferer can be functionally defined as one which is not transmitting continuously, but which is on-the-air long enough that the same procedures can be used to locate it. An interferer can be classified as 'short duration' based on two characteristics. The first of these is the most obvious – namely, an interferer is 'short-duration' when it transmits only for very brief periods of time (i.e. has a short duty cycle). Sometimes these types of signals are also referred to as 'bursty' or 'intermittent.' The length of these on-air times can range from milliseconds (or less) to several seconds. There can be considerable variation in the behavior of intermittent signals. Some non-constant signals repeat themselves on a regular interval, whereas others repeat themselves on irregular intervals. Many have no discernible pattern at all. It is also safe to classify all frequency-hopping signals as 'short-duration.'

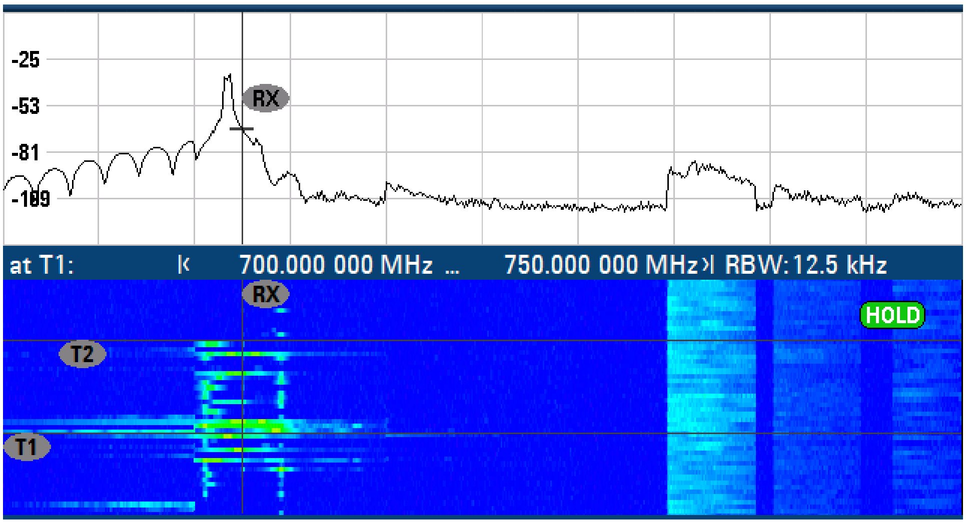

Figure 1 - A short duration interferer

However, there is another, less obvious type of 'short duration' interferers, and these often are more common than those mentioned above. In this case, the 'short-duration' interferers may, in fact, be constant / long duration signals, but are only visible for a short period of time – that is, the signal has a very short 'detection distance.' This occurs very frequently when vehicles are used – the interferer may be transmitting constantly, but it is only seen for a brief period of time while driving near or past the source location.

Of course, it is also possible for a signal to be short-duration for both reasons – short duty cycle and short detection distance. This represents the most challenging of all types of interferers and is the best example of where the use of high-speed instruments makes a significant difference in the ability to detect and locate sources of interference.

3 SPECTRUM ANALYZERS AND MONITORING RECEIVERS

In order to look for interference, we need instruments that are capable of receiving and displaying radio frequency spectrum. Until recently, almost all interference hunting was conducted using swept spectrum analyzers. As the name implies, a spectrum analyzer is a device which collects, processes, and displays information about radio frequency signals (spectrum), and present this information as a graph of level vs. frequency over a specified frequency range. 'Swept' spectrum analyzers convert the input signal to an intermediate frequency (IF) using a mixer and a local oscillator (LO). This signal is swept past a fixed-tuned filter to determine resolution bandwidth. The resulting signal is then logarithmically amplified and passed to the display.

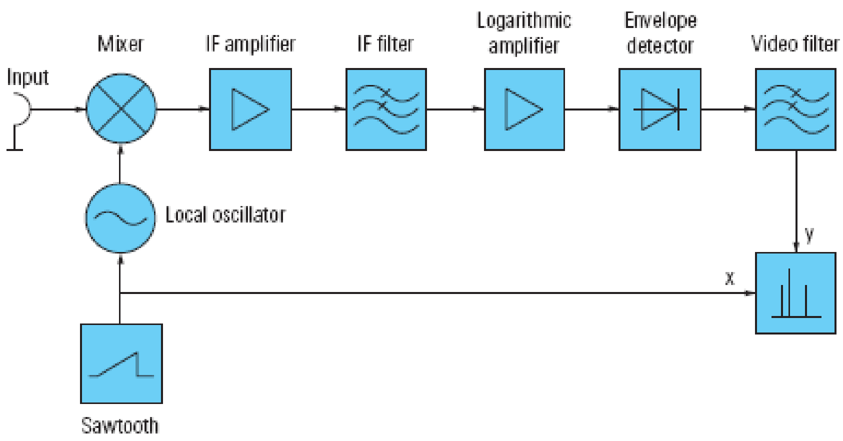

Figure 2 - Typical swept spectrum analyzer architecture

Because of their internal architecture, swept spectrum analyzers require the user to specify a number of parameters (such as resolution bandwidth, video bandwidth, etc.), and careful selection of these parameters is needed to avoid problems during interference hunting. For example, span should be set so that it includes the frequencies of interest, but too wide of a span makes it difficult to see signal details clearly. Another drawback of a very wide span is that it takes a longer time to cover this span. The resolution bandwidth (RBW) determines how well a spectrum analyzer can separate adjacent frequencies and also has an effect on the displayed noise: if the resolution bandwidth is small, the displayed noise drops. In most spectrum analyzers RBW is usually coupled to the span, such that as the RBW is reduced, the span is also reduced.

The most serious limitation in using swept spectrum analyzers for interference hunting is that this swept architecture may miss the target signal during a sweep. A swept spectrum analyzer only ‘sees’ signals which fall within the RBW filter at the current point in the sweep – any short duration signals which are occurring at other frequencies within the span will not be detected or displayed. Even relatively high-duty cycle signals may be missed if the on-air times are effectively ‘out of sync’ with the sweep.

Monitoring receivers based on the FFT (Fast Fourier Transform) principle are similar to spectrum analyzers in that they display information about radio frequency signals, but the way in which they acquire and process this information is very different from the method used in swept spectrum analyzers.

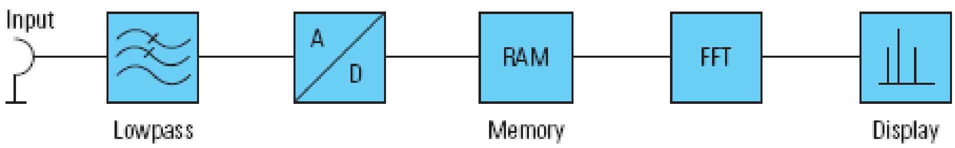

Figure 3 - Typical FFT-based receiver architecture

As the name implies, FFT-based instruments calculate the receiver’s IF spectrum using the Fast Fourier Transform. The use of FFT provides two major advantage compared to a swept spectrum analyzer. The first of these is that they offer extremely high sensitivity due to the very fine ‘bins’ used in the calculations. As a result, FFT-based receivers are also better at separating signals that are close to each other in frequency. Furthermore, the use of small bin widths results in FFT-based receivers having a sensitivity that is far superior to that of conventional swept spectrum analyzers. Both of these greatly increase the probability of intercept for short-duration interferers.

It is also important to note that although swept spectrum analyzers may use FFT processing in some portion of their signal processing chain, the speed and sensitivity improvements obtained from FFT processing require true FFT-based receiver. A swept analyzer which (optionally) employs FFT processing (“burst mode” or similar) only at particular stages will not show the same performance improvements as a purely FFT-based receiver.

The spectrum update rate, i.e. the speed at which measured changes in spectrum are displayed on the instrument, is also of crucial importance in interference hunting, since the ability to see changes in spectrum in near real-time is a function of both the signal processing chain as well as the way in which this information is presented to the user.

4 DIRECTION FINDING SYSTEMS

Direction finding (or ‘radiolocation’) systems are also commonly used in interference hunting. Direction finding techniques and tools can be used as soon as the target frequency is known – the above-mentioned ‘second phase’ of interference hunting. There are two main categories of direction finding: manual and automatic.

Manual direction finding is the oldest and best known method of determining the direction towards a signal source. Manual direction finding using a directional antenna is relatively straightforward – simply move or rotate the directional antenna until maximum received signal strength is obtained, and then record the azimuth or ‘bearing’ towards the target. If numerous bearings are obtained from different locations, these bearings can be combined to estimate the most probable location of the signal source – a process called ‘triangulation’. While manual direction finding is relatively inexpensive and easily understood, it is rarely the fastest, easiest, or most accurate way to obtain a rough location fix. Depending on the radio frequency environment, nature of the target signal, and skill level of the operator, manual direction finding can often become an extremely time consuming (and frustrating) experience.

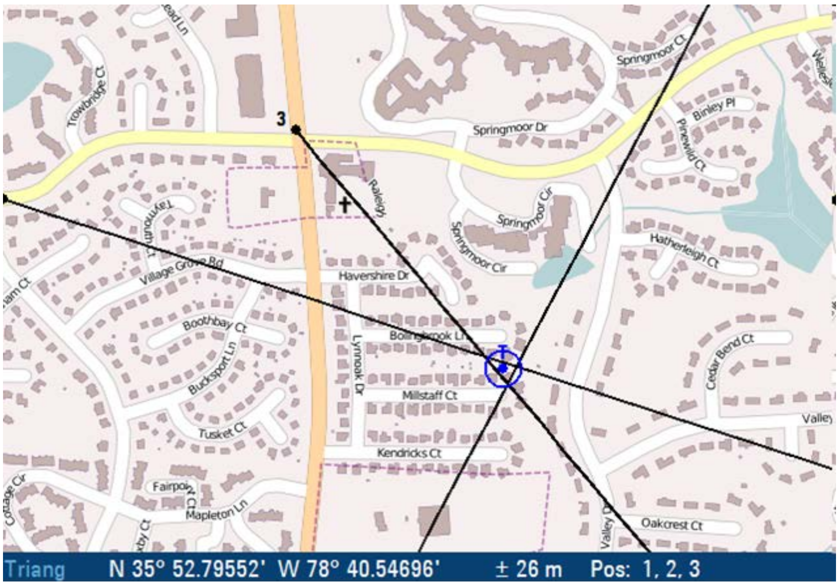

Figure 4 - Triangulation result based on manually obtained bearings

Automatic direction finding systems differ from manual direction finding in that they uses one or more direction finding methodologies (such as Doppler, Watson-Watt, Correlative Interferometry, etc.) to obtain a bearing towards a signal – the operator specifies the target frequency and the system automatically determines the bearing. Needless to say, automatic direction finding systems require both specially designed direction-finding antennas and specialized direction-finding receivers. Automatic direction finding systems reduce the time needed for interference hunting in a variety of ways.

The first scenario is when the signal that is very far away (on the order of several miles), since the change in received level may not measurably change while driving short distances. Taking manual bearings on distant transmitters can also be problematic, since small bearing errors become quite large errors at long distances – a 5 degree bearing error on a transmitter 100 meters away translates into an error distance of approximately 8.7 meters. The same bearing error on a transmitter 5 kilometers away results in an error distance of 437 meters.

In order to take a manual bearing towards a signal source, that signal must be on-the-air long enough to rotate the antenna (possibly more than once) and determine the point at which the received signal level is a maximum. The time required to take a manual bearing depends on the instrument / antenna used, the type and level of signal, and the skill of the operator, but is usually on the order of 15-60 seconds. Therefore it becomes very difficult to obtain a good bearing on signals which are on the air for less than this period of time, with the difficulty increasing substantially as the on-air time decreases. Below a certain threshold (~5 seconds signal duration) even the most experienced operator using the fastest and most sensitive equipment will not be able to reliably obtain a manual bearing on a non-constant signal. In this case, automatic direction finding systems are very helpful, since they can take bearings even on very short-duration signals (well under 1 second) and determine locations based on this information even when the signal has an extremely transmit times.

But perhaps the most significant advantage of automatic direction finding system is in high multipath environments. The term multipath refers to the situation in which the received signal takes different paths to reach the receiver. Multipath is most commonly the result of highly reflective environments, i.e. environments in which there are many buildings and other obstructions which reflect or otherwise interfere with line-of-sight propagation between transmitter and receiver. Multipath can greatly increase the time it takes to perform manual direction finding – to obtain good manual DF results, bearings must be taken from locations with low multipath to ensure that these bearings do in fact point towards the signal source. Unfortunately, such low-multipath locations are very difficult to find and very difficult to access, especially in urban and semi-urban environments. For example, the roof of a tall building is usually a very good site for obtaining manual bearings (low multipath), but gaining access to such a location is often difficult and time consuming. In many cases these environments are also not (easily) accessible by vehicles. Given that three (preferably more) bearings are required for a valid triangulation calculation, one could easily spend an entire day just obtaining access to low-multipath bearing locations, assuming of course that such locations exist. On the other hand, newer automatic direction finding methodologies, especially those based on more multipath-immune technologies such as correlative interferometry, can obtain large numbers of bearing results and use these results to calculate emitter location, even while operating in medium- to high-multipath environments and without requiring careful selection of measurement locations. This can represent a significant time savings over the ‘stop and stare’ approach using manual direction finding.

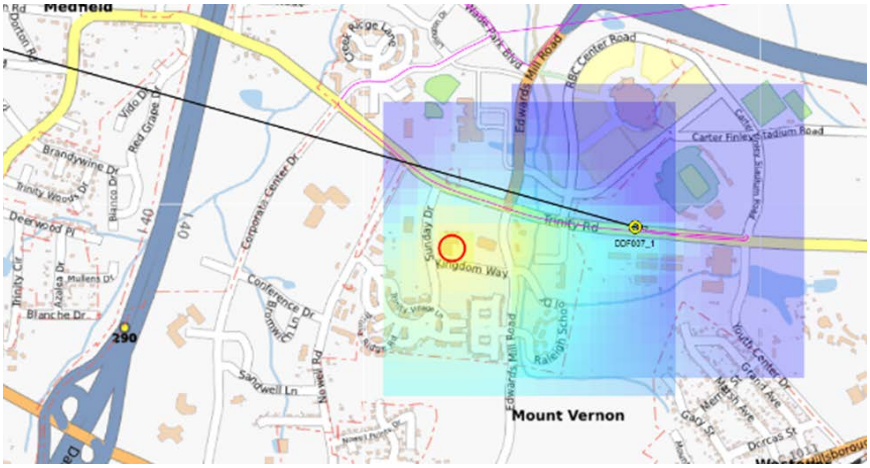

Figure 5 – Position fix obtained from an automatic direction-finding system

5 FINAL STEPS

Once the rough location (within ~ 100 meters) of the target signal is determined the final step involves manually searching the area to locate the device which is generating the interferer. Usually this is done by examining the area with a handheld antenna, using received level, waterfall intensity, or an audio signal whose level corresponds to the received RF signal level. Speed is important here as well – an instrument must react quickly to avoid false (i.e. delayed) results without requiring impractically slow movement of the handheld antenna. The situation is analogous to the 'driving around' phases of interference hunting – if the instrument does not respond quickly enough to the signal, it is quite possible to walk past the signal source without detecting it. This will also greatly increase the time needed to complete the final (and arguably the most important) step of the interference hunting process.

6 PRACTICAL EXAMPLES

The importance of speed in interference hunting is perhaps best illustrated using examples of common real-world interferers.

The first of these is intermodulation products. Intermodulation products occur when two signals mix in a non-linear device. In most cases of real-world interference, one of the signals mixing to create the intermodulation product is a bursty or intermittent signal. For example, paging systems are a very common component in intermodulation issues because they are relatively high-powered transmitters located in urban environments, with their antennas near to (or even collocated with) other services. Intermodulation products will occur only when both signals are present, meaning that if one or more of the component signals are intermittent, the products will also be intermittent. In the case of paging, the transmissions are often no more than several seconds long, making manual location of the intermodulation products extremely difficult.

As mentioned above, short duration or 'bursty' noise pulses represent a significant and difficult-to-locate source of interference. Although as rule, interferers must be 'on-the-air' for a certain minimum period of time in order to cause interference, short-duration signals can create serious issues when their transmit power is very high. These short-duration signals may be intentional (such as radar pulse) or unintentional. Low-quality transmitters may generate an off-frequency burst of energy when they are first powered-up or when their transmit frequency changes. In all cases, these types of short-duration interferers are also very difficult to locate for the same reasons mentioned above

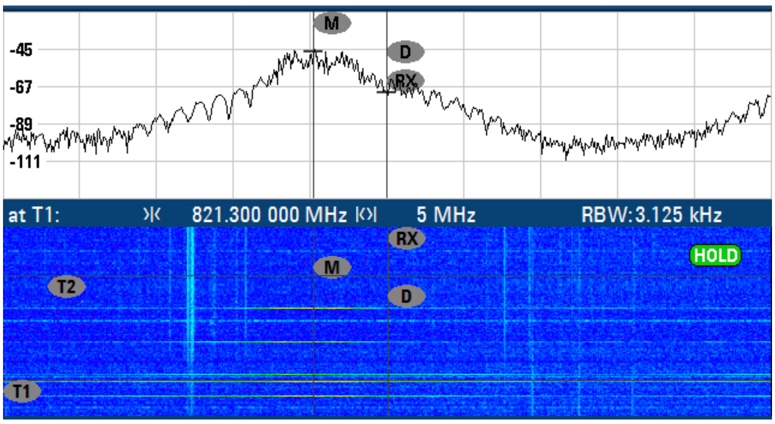

Figure 6 - Short noise burst

Another example of a 'short duration' signal that is, in fact, a constant signal, is cable egress. Cable television systems use the same frequencies used by over-the-air services but interference is avoided due to the shielding provided by the cables and other devices in the cable network. Faults in this infrastructure can lead to signals egressing or 'leaking' from the cable system, and this has become one of the largest causes of interference in 700 MHz LTE networks in the United States. In many cases, cable egress causes problems for cellular base stations even at levels that can only be detected on the ground for a distance of only a few dozen meters. Since an automobile traveling at 65 mph covers almost 100 feet per second, it is quite possible to drive past a serious cable leak before a single sweep is made on a traditional spectrum analyzer, especially when a wider span is used.

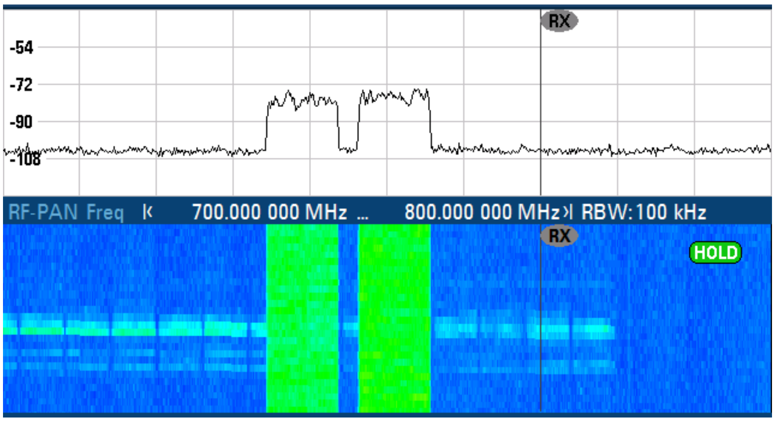

Figure 7 – 'Short duration' cable egress (seen while driving) shown in waterfall display

7 CONCLUSION

Short-duration signals are a frequent cause of interference. Interferers may be classified as 'short-duration' based on their short duty cycle/transmit time, a short detection distance, or both. Although detecting and analyzing low probability of intercept signals has historically been of interest primarily in military, law-enforcement, and government applications, the need for high-speed and high-performance receivers has now become commonplace in commercial networks as well. FFT-based monitoring receivers offer significant advantages in terms of both speed and sensitivity compared to swept spectrum analyzers. Similarly, recent advancements in automatic direction finding systems have leveraged the unique capabilities of FFT-based receivers in order to provide quick and accurate location of even short duration emitters.

8 REFERENCES

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