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Rapid Determination of Receiver Sensitivity via Integral Search

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Rapid Determination of Receiver Sensitivity via Integral Search

ABSTRACT

Receiver sensitivity is a measure of the lowest signal strength that a receiver can detect. Receiver sensitivity is typically measured by linearly incrementing the received power level until a target packet error rate (PER) is reached. Linear search is slow and can occupy substantial test resources such as test stations and instruments. This disclosure describes techniques to rapidly determine the receiver sensitivity of a device-under-test (DUT) by learning the ensemble characteristics of devices under test, building a packet error rate (PER) model, performing limited-range measurements of the DUT, and using the PER model and the results of the measurements to predict the sensitivity of the DUT. By speeding up the determination of receiver sensitivity, the described techniques reduce test cycle times and enable improvement of the units per hour (UPH) of a factory, resulting in a lower cost of owning and operating test stations and instruments.

KEYWORDS

- Receiver sensitivity
- Test cycle
- Device testing
- Golden device
- Integral search
- Packet error rate (PER)
- Spike noise
- Broadband noise

BACKGROUND

Receiver sensitivity is a measure of the lowest signal strength that a receiver can detect. For example, sensitivity can be defined as the received power level, expressed in dBm, at which the packet error rate (PER) is a certain percentage, e.g., 10%. At a factory or validation lab, receiver sensitivity is typically measured using linear search, e.g., by linearly incrementing the dB-level until the target PER is reached. Linear search is slow and can occupy substantial test resources such as test stations and instruments. Under linear search, a target units-per-hour (UPH) requirement in the factory is met by a corresponding increase in the number of test stations, representing a substantial sunk investment.

DESCRIPTION

This disclosure describes techniques to rapidly determine the receiver sensitivity of a device-under-test (DUT) by learning the ensemble characteristics of devices under test, building a packet error rate (PER) model, performing limited-range measurements of the DUT, and using the PER model and the results of the measurements to predict the sensitivity of the DUT.

The PER model, based on data collected over an ensemble of devices, includes a known sensitivity, referred to as the golden sensitivity. The golden sensitivity is the dBm level at which a hypothetical device (referred to as golden device) representing an average of the ensemble achieves a target (e.g., 10%) PER rate. The sensitivity of a given DUT can be determined as the distance (in dBm) from the golden sensitivity.

Testing is performed by lowering the power level of the vector signal generator (VSG) to below a certain level (e.g., 3 dB) of the golden sensitivity and raising the power level in predefined steps to a certain level (e.g., 3 dB) above the golden sensitivity. At each power step, the DUT tracks the number of packets received free of error. When the sequence of power increments is completed, the total number of error-free packets that have been received by the DUT is determined.

The total number of error-free packets is indexed into the sensitivity curve of the golden device to determine the distance in dBm between the sensitivities of the golden device and the DUT, thereby determining the sensitivity of the DUT. While determination of the golden sensitivity can occur over a large power range (e.g., 30 dB), a given DUT is subject to power testing over a smaller power range (e.g., ∓ 3dB from the golden sensitivity). The limited range over which the DUT is tested contributes to enabling faster testing.

In contrast to the traditional determination of receiver sensitivity, the DUT is queried for the total number of error-free packets at the end of the power-level sequence, e.g., the number of error-free packets at each power level is not considered. Effectively, the described techniques do not directly compare the PER curves of the DUT and of the golden device. Rather, the comparison is of the areas under the respective PER curve. Therefore, the described techniques for determining receiver sensitivity can be termed as *integral search*. Integral search reduces the communication overhead between the DUT and the test equipment, further reducing the time for device characterization.

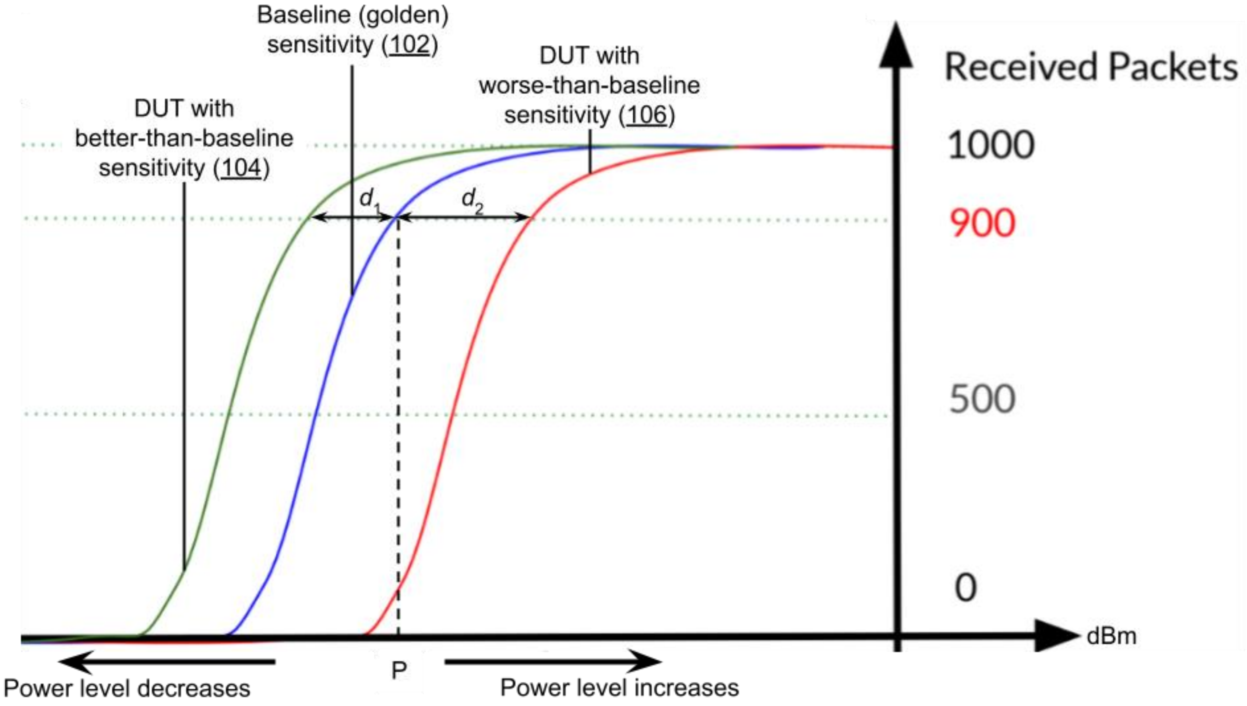


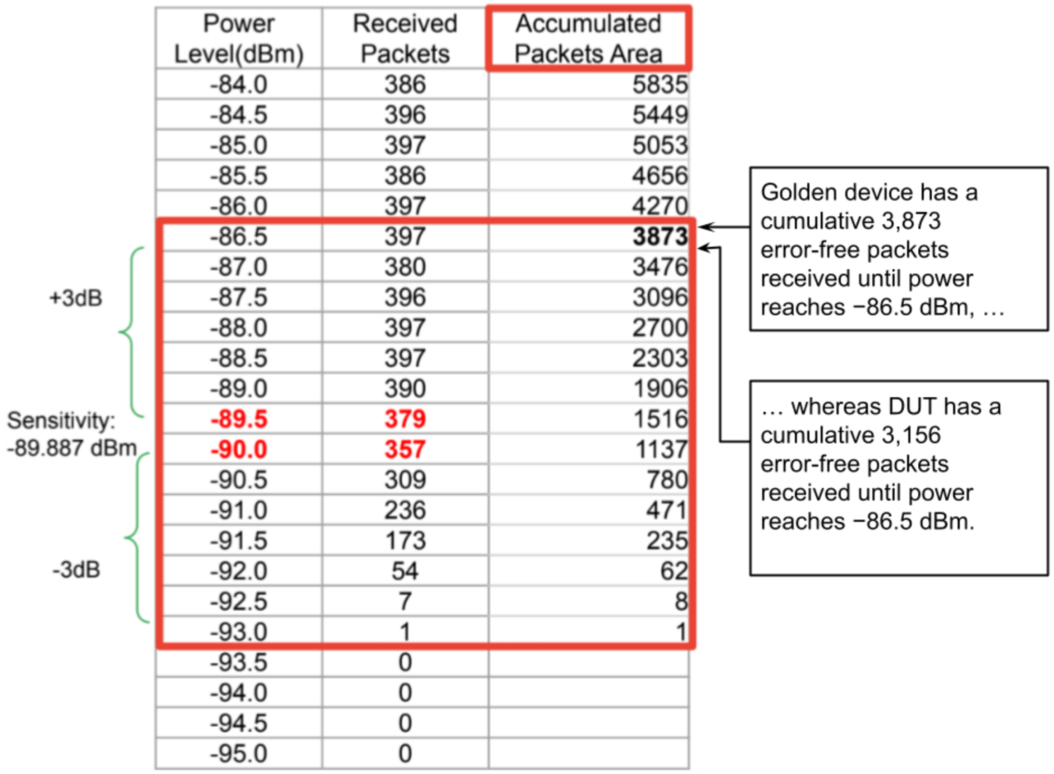
Fig. 1: Measurement of the sensitivity of a DUT as the distance between its PER curve and that of a golden device

Fig. 1 illustrates measurement of the sensitivity of a given DUT as the distance between its PER curve and that of a golden device. The X-axis represents received power in dBm. In this example, at each power level, a thousand packets are transmitted. The Y-axis represents the number of packets received at various power levels. A golden device exhibits the blue (baseline) PER curve (102). Sensitivity is defined at the power level that yields a 10% PER, e.g., 900 error-free packets received out of 1000. The golden device has a sensitivity of P dBm.

A device with sensitivity better than the golden sensitivity has a PER curve to the left of the baseline sensitivity. For example, the green curve (104) is d_1 dB to the left of the baseline PER curve at a PER of 10%. Thus, the green curve represents a device with a sensitivity of $P - d_1$ dBm, e.g., superior to the golden device by d_1 dB.

A device with sensitivity worse than the golden sensitivity has a PER curve to the right of the baseline sensitivity. For example, the red curve (106) is d_2 dB to the right of the baseline PER curve at a PER of 10%. Thus, the red curve represents a device with a sensitivity of $P + d_2$ dBm, e.g., inferior to the golden device by d_2 dB.

Example



Power Level(dBm)	Received Packets	Accumulated Packets Area
-84.0	386	5835
-84.5	396	5449
-85.0	397	5053
-85.5	386	4656
-86.0	397	4270
-86.5	397	**3873**
-87.0	380	3476
-87.5	396	3096
-88.0	397	2700
-88.5	397	2303
-89.0	390	1906
-89.5	**379**	1516
-90.0	**357**	1137
-90.5	309	780
-91.0	236	471
-91.5	173	235
-92.0	54	62
-92.5	7	8
-93.0	1	1
-93.5	0	
-94.0	0	
-94.5	0	
-95.0	0	

Golden device has a cumulative 3,873 error-free packets received until power reaches −86.5 dBm, …

… whereas DUT has a cumulative 3,156 error-free packets received until power reaches −86.5 dBm.

Golden PER curve: Sensitivity is -89.887 dB

Fig. 2: Rapid determination of receiver sensitivity using integral search

Fig. 2 illustrates rapid determination of receiver sensitivity using integral search. The table illustrated is the PER curve of a golden device, which is found to have a sensitivity of −89.887 dBm. The second column represents the number of error-free packets received at each power level of the first column. The third column represents the area under the PER curve. For example, as the power is swept from −95.0 dBm to −89.5 dBm, a total 1,516 (=0+0+0+0+1+7+54+173+236+309+357+379) packets were received free of error.

A given device under test is characterized for performance between ∓ 3dB of the sensitivity of the golden device, e.g., between −93.0 dBm to −86.5 dBm in this example. At each step (power level), 400 packets are sent. The DUT is found at the upper power limit (−86.5 dBm) to have received a total 3,156 packets free of error. Indexing 3,156 packets back to the PER curve of the golden device, the golden device is found to have reached a performance of 3,156 packets somewhere between −87.5 dBm and −87.0 dBm, or, linearly interpolating, at a precise dBm level of −87.4 dBm. The distance between the given DUT and the golden device is thus 87.4−86.5 = 0.9 dB. The sensitivity of the given DUT is therefore determined to be −89.887 + 0.9 = −88.9 dBm.

While undergoing device characterization by integral search, all receiver features of the DUT need not be enabled; rather, it is sufficient to enable just the RF receiving mode (e.g., the WiFi RF mode, if the device operates under the 802.11 family of wireless protocols).

In this manner, by substantially speeding up the determination of receiver sensitivity (e.g., by a factor of four as compared to linear search in the case of WiFi devices), the described techniques reduce test cycle times and enable improvement of the units per hour (UPH) of a factory, resulting in a lower cost of owning and operating test stations and instruments. The described techniques can determine receiver sensitivity under noiseless conditions or when noise is injected, e.g., to simulate receiver desensitization caused by an electromagnetic aggressor.

CONCLUSION

This disclosure describes techniques to rapidly determine the receiver sensitivity of a device-under-test (DUT) by learning the ensemble characteristics of devices under test, building a packet error rate (PER) model, performing limited-range measurements of the DUT, and using the PER model and the results of the measurements to predict the sensitivity of the DUT. By speeding up the determination of receiver sensitivity, the described techniques reduce test cycle times and enable improvement of the units per hour (UPH) of a factory, resulting in a lower cost of owning and operating test stations and instruments.

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