

**SEMICONDUCTOR DEVICE FOR ARTICLE IDENTIFICATION USING
INTERMODULATION PRODUCT OF DIFFERENT INTERROGATION FREQUENCIES**

TECHNICAL FIELD OF THE INVENTION

The present invention relates to harmonic article identification, and more particularly, the invention relates to identification of an article carrying at least one semiconductor device outputting an harmonic intermodulation for detection and/or
5 identification.

BACKGROUND OF THE INVENTION

There has been significant effort in the last decade or so to develop systems for identification of products, either identification of a particular product from a product signature or identification of products moving through a defined space. This
10 effort has resulted in a number of product identification systems utilizing various technologies to generate and evaluate product identification signals. One of the most widely used system utilizes a bar code reader response to a bar coded element carried by a product or article. As the bar coded element moves through a scanning field, the
15 response to the scanning field changes and this change is detected. Such systems are primarily intended only for identification of products or articles moving through a defined space, although there is no technological limitation to generate identification signatures. These systems are restricted in the areas of utilization due to size and cost restraints.

20 Other known systems utilize transponder tags carried or otherwise attached to a product or article. Many of these transponders are expensive and have a limited range of detection, typically, less than one meter. There is no known transponder tag detection system that utilizes harmonic detection for article identification. Again, transponder tags have found limited use due to the size of the transponder and the cost
25 of a tag that may be utilized once and discarded.

In addition to monitoring and tracking articles and products, identification systems presently in use also find utility in security applications. This includes document security where size of the tag has a more significant impact than tags used for article and product identification for monitoring and tracking. Systems presently
30 in use for article identification including product identification and document

identification do not provide a security identification signature or "fingerprint" for a document. The use of an identification signature enables the recognition of individual articles or articles in groups identified with a common identification signature.

Thus, there is a need for an article identification system utilizing a relatively inexpensive tag or detector element and having a size that does not burden the article for identification. Further, there is a need for an article identification system utilizing a tag that provides an identified signature to separate identified articles into classes.

SUMMARY OF THE INVENTION

In accordance with example embodiments of the present invention, there is provided an inexpensive system and method for identifying articles carrying one or more semiconductor devices that respond to RF frequencies and radiate harmonic modulation energy. An harmonic article identification tag may comprise at least one RF diode carried by an article and responsive to at least two RF frequencies to generate a third harmonic intermodulation output.

An harmonic intermodulation article identification system may comprise at least one semiconductor device carried by or attached to an article. The at least one semiconductor device may respond to at least two RF frequencies to generate an harmonic intermodulation output. This harmonic intermodulation output RF signal may be received by an antenna having an output connected to a signal analyzer. This signal analyzer may respond to the analyzer signal to identify the article carrying the at least one semiconductor device.

According to a first aspect of the present invention, there is provided a system for identifying an article carry a diode, the system comprising: a first signal generator operable to generate a first high-frequency signal; a second signal generator operable to generate a second high-frequency signal; one or more diodes carried by the article and responsive to high-frequency signals, each of the one or more diodes being carried by an article and being operable to: receive the first and second high-frequency signals; and in response to receiving the first and second high-frequency signals, generate a unique harmonic signal; an antenna operable to: receive the harmonic signal generated by the diode; and communicate the harmonic signal to a

2a

signal analyzer coupled to the antenna; and the signal analyzer operable to match the harmonic signal to an article type to identify the article.

According to a second aspect of the present invention, there is provided a method for identifying an article carrying a diode, the method comprising: generating a first high-frequency signal; generating a second high-frequency signal; receiving one or more harmonic signal generated by one or more diodes carried by the article in response to the one or more diodes receiving the first and second high-frequency signals, each of the one or more diodes being responsive to high-frequency signals and being carried by an article; communicating the one or more received harmonic signals for matching to an article type; and matching the harmonic signal to an article type to identify the article.

According to a third aspect of the present invention, there is provided a system for identifying an article carrying a diode, the system comprising: means for generating a first high-frequency signal; means for generating a second high-frequency signal; means for receiving one or more harmonic signals generated by one or more diodes carried by the article in response to the one or more diodes receiving the first and second high-frequency signals, each of the one or more diodes being responsive to high-frequency signals and being carried by an article; means for communicating the one or more received harmonic signals for matching to an article type; and means for matching the harmonic signal to an article type to identify the article.

A method for harmonic article identification may comprise generating at least two RF signals at

separate frequencies. In response to the two separate frequencies, an harmonic intermodulation signal may be generated by at least one RF diode carried by an article and responsive to the at least two separate frequencies. An analyzer signal may be generated at the output of an antenna receiving the harmonic intermodulation output and this analyzer signal is analyzed to generate an article identification signature.

In addition, there may be provided an identification system for articles carrying at least one semiconductor device that generates an harmonic intermodulation output. The identification system may comprise a signal analyzer responsive to the harmonic intermodulation output to generate an article identification signal applied to a comparator. Also coupled to the comparator may be a signature memory storing the article identification signatures of at least one article for identification. The comparator may respond to the article identification signal from the signal analyzer and scan each of the article identification signatures stored in the signature memory. The comparator may generate a signal to identify an article carrying at least one semiconductor device from the stored signatures.

Technical advantages of the example embodiments include an inexpensive system and method for identifying articles tagged with at least one semiconductor device. The system may identify both from far (one to three meters) and near (less than one centimeter) environments. A further advantage of the example embodiments is the utilization of inexpensive RF diodes and strong RF signals to detect harmonics at a distance not heretofore possible by use of near field antenna apertures to scan the article and record an identification signature to be verified. A further technical advantage of the example embodiments is cost reduction and expansion of opportunities for identification in areas of monitoring, tracking and security that have heretofore been prohibited due to the size and cost restraints of tags and responding systems.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGURE 1 is schematic diagram of an identification system utilizing microwave horn antennas radiating a semiconductor device to generate a third harmonic intermodulation signal;

FIGURE 2 is a block diagram of a signal analysis system responsive to a third harmonic intermodulation signal to identify a substrate; and

FIGURE 3 is a flow diagram of the process for generating article identification utilizing two RF signals for radiating RF diodes in a substrate for identification.

DETAILED DESCRIPTION OF THE INVENTION

5 Although the invention will be described with reference to identification of a signature on a document, it should be understood that this is a preferred embodiment and the invention finds utility in many applications other than document signature identification. For example, and not by way of limitation, the harmonic intermodulation system and method of the present invention may be utilized for
10 identification of the presence of a document without specifically identifying individual documents. Further, the invention finds utility in identification of the signature or presence of articles other than documents carrying at least one RF diode that generates a third harmonic intermodulation output. Thus, the invention finds utility in commercial and government uses for classified and unclassified documents
15 and other articles.

Referring to FIGURE 1, there is illustrated a schematic diagram of a system for identifying an RF tagged article for signature recognition of a multiple tagged article. The RF tag system 10 of FIGURE 1 comprises a first frequency generator 12 generating a first frequency signal applied to a microwave horn antenna 16. A second
20 frequency generator 14 outputs a second frequency applied to a microwave horn antenna 18. Typically, the horn antennas are positioned to radiate an RF diode 20 at right angles to the diode. In the embodiment of the invention illustrated in FIGURE 1, the signal generator 12 may be a Hewlett-Packard frequency generator outputting the first frequency F1 at 24.0 GHz @ +4.0 dBm. The second signal generator 14 may
25 also be a Hewlett Packard frequency generator outputting the second frequency F2 at 24.1 GHz @ +4.0 dBm. With a first frequency of 24.0 GHz and a second frequency of 24.1 GHz, the RF diode 20 comprises a 24.0 GHz beam lead type. Such diodes are commercially available and have a size configuration to enable embedding in a document such that the diode is not visually apparent.

30 Although the invention will be described with reference to a first frequency of 24.0 GHz and a second frequency of 24.1 GHz, it should be understood that this is a

preferred embodiment and other RF frequencies may be used in implementation of the invention.

Radiating the diode 20 with the first frequency from the signal generator 12 and the second frequency from the signal generator 14 results in the diode producing a
5 third order intermodulation product. This harmonic signal is detected by a dipole antenna 22 that outputs an analyzer signal to a spectrum analyzer 24. The spectrum analyzer 24 responds to the analyzer signal to generate a signature display 26 that identifies the presence of the diode 20 and the intermodulation output. The spectrum analyzer 24 also outputs a signature signal for additional processing of the analyzer
10 signal from the dipole antenna 22.

In operation of the system of FIGURE 1, the signal generator 12 outputs a frequency at 24.0 GHz and the signal generator 14 outputs a 24.1 GHz frequency. These two frequencies are applied to the horn antennas 16 and 18, respectively, to radiate the RF diode 20 thereby generating a third order intermodulation product
15 detected by the dipole receiver antenna 22. For the specific frequencies of 24.0 GHz and 24.1 GHz, the third order intermodulation product would be two RF frequencies at 23.9 GHz and 24.2 GHz. When the first frequency F1 is 24.0 GHz and the second frequency F2 is 24.1 GHz, then the analyzer signal from the dipole antenna 22 varies in accordance with the expression $2F1 - F2 = 23.9 \text{ GHz}$ or in accordance with the
20 expression $2F2 - F1 = 24.2 \text{ GHz}$. With power levels from the signal generators 12 and 14 of approximately +4.0 dBm, the spectrum analyzer 24 responds to third order intermodulation products in the -100 dBm range.

Referring to FIGURE 2, there is illustrated a block diagram of an RF tagging system 30 for identification of RF diode signatures in a substrate 32, such as a
25 document or article tag. One or more RF diodes 34 are embedded in or carried by the substrate 32 in a selected "x-y" coordinate position. The one or more diodes 34 are radiated by frequency signals from RF frequency generators, such as signal generators 12 and 14 of FIGURE 1. Radiating the one or more RF diodes 34 creates a signature intermodulation output that uniquely identifies the document carried by the diodes. In
30 addition, the x-y coordinate position of the diodes 34 on the substrate 32 provides further authentication of the substrate. Thus, the signature of the radiated RF diodes

34 identifies the substrate, for example, a document or tag, and the x-y coordinate position of the diodes authenticates the signature.

Due to the square law characteristic of high frequency RF diodes, when the diodes 34 are exposed to a radiated RF field from signal generators 12 and 14, the diodes will both produce and re-radiate harmonic related RF energy. This re-radiated RF harmonic energy, for example, a third harmonic intermodulation product, is received by a scanning dipole antenna 36. As the substrate 32 passes in proximity to the scanning dipole antenna 36, the antenna identifies the x-y coordinate position of the diodes 34 and also responds to the signature identification resulting from the radiation of the diodes. This diode position information and the signature identification received by the dipole antenna 36 is applied to a spectrum analyzer 38. The spectrum analyzer 38 responds to the applied position information and signature identification to output a spectrum analyzer signal coupled to a comparator 40. Also coupled to the comparator 40 is a signature memory 42 that stores signature identification data for all substrates (documents, tags) to be identified by the system. The signature identifications stored in the memory 42 are pre-programmed into the system by applying signature identification data on a line 44 coupled to the comparator 40.

When the comparator 40 receives position information and a signature identification from the spectrum analyzer 38, the data stored in the signature memory 42 is scanned and when a comparison results the comparator 40 outputs an identification signal to a display 46. The display 46 comprises a visual presentation or hard copy printout identifying the substrate 32 and authenticating the substrate.

Referring to FIGURE 3, there is illustrated a flow diagram of the process for identifying RF tagged articles. Two RF signals are generated at an initial process sequence 50. These two RF frequency signals are applied to microwave horn antennas 16 and 18 to radiate RF diodes during process sequence 52. The RF diodes carried by or embedded in a document, tag or other substrate radiate third order intermodulation products received by a dipole antenna to generate a product signature at process sequence 54. The product signature is applied to an inquiry sequence 56 to evaluate if the product signature is a new signature not previously received. A

positive response to the inquiry sequence 56 directs the product signature to a memory during a store process sequence 58.

A negative response to the inquiry sequence 56, indicating that the product signature from the process sequence 54 is not new, advances the process for article
5 identification to a scanning process sequence 60. During the scanning process sequence 60, the product signature from the process sequence 54 is compared with the store product signatures in the scanning process sequence 60. A positive comparison between an incoming product signature and one of the stored product signatures advances the identification process to generate an article identification during a
10 process sequence 62.

In addition to document identification by product signature, the process of FIGURE 3 also finds utility in identification of the authenticity of a document. Instead of the document carrying one or more embedded RF diodes defining a product signature, the document would carry only one RF diode. The process of FIGURE 3 is
15 modified to remove the process sequences 56, 58 and 60 and the product signature from the process sequence 54 comprises a signal identifying the presence of an RF diode in a document. The presence of the RF diode in the document is an indication of authenticity of the document as generated in the process sequence 62.

While the invention has been described with reference to the illustrated
20 preferred embodiment, it is intended to cover such alternatives, modifications and equivalents as may be included in the spirit and scope of the invention as defined in the following claims.

CLAIMS:

1. A system for identifying an article carry a diode, the system comprising:

a first signal generator operable to generate a first high-frequency signal;
a second signal generator operable to generate a second high-frequency signal;
one or more diodes carried by the article and responsive to high-frequency signals, each of the one or more diodes being carried by an article and being operable to:

receive the first and second high-frequency signals; and
in response to receiving the first and second high-frequency signals,
generate a unique harmonic signal;

an antenna operable to:
receive the harmonic signal generated by the diode; and
communicate the harmonic signal to a signal analyzer coupled to the
antenna; and

the signal analyzer operable to match the harmonic signal to an article
type to identify the article.

2. The system of Claim 1, wherein:

each of the one or more diodes has a fixed location with respect to the article
the one or more fixed locations providing a further parameter in identifying the
article;

the antenna is further operable to:
detect the one or more fixed locations; and
communicate the one or more detected fixed locations to the signal analyzer;
and

the signal analyzer is further operable to process the particular fixed
locations to identify the article.

3. The system of Claim 2, wherein each of the one or more fixed
locations are determined according to only an x coordinate and a y coordinate.

4. The system of Claim 1, wherein each of the diodes has a size and a weight that are at least relatively negligible with respect to a size and a weight of the article.

5. The system of Claim 4, wherein:
the article is a document; and
each of the diodes is embedded in a paper of the document.

6. The system of Claim 1, wherein:
the first high-frequency signal has a first frequency of approximately 24.0 GHz;
the second high-frequency signal has second frequency of approximately 24.1 GHz; and
each of the diodes is responsive to the first and second high-frequency signals.

7. The system of Claim 1, wherein the harmonic signal is a third-order intermodulation product of the first and second high-frequency signals.

8. The system of Claim 7, wherein the harmonic signal corresponds to $2F_1 - F_2$ or $2F_2 - F_1$, the first high-frequency signal being approximately equal to F_1 , the second high-frequency signal being approximately equal to F_2 .

9. The system of Claim 1, wherein a frequency of the harmonic signal is used to match the harmonic signal to an article type.

10. A method for identifying an article carrying a diode, the method comprising:
generating a first high-frequency signal;
generating a second high-frequency signal;
receiving one or more harmonic signal generated by one or more diodes carried by the article in response to the one or more diodes receiving the first and second high-frequency signals, each of the one or more diodes being responsive to high-frequency signals and being carried by an article;

communicating the one or more received harmonic signals for matching to an article type; and

matching the harmonic signal to an article type to identify the article.

11. The method of Claim 10, wherein:

each of the one or more diodes has a fixed location with respect to the article, the one or more fixed locations providing a further parameter in identifying the article;

the method comprising:

detecting the one or more fixed locations;

communicating the one or more detected fixed locations; and

processing the one or more detected fixed locations to identify the article.

12. The system of Claim 11, wherein each of the one or more fixed locations are determined according to only an x coordinate and a y coordinate.

13. The system of Claim 10, wherein each of the diodes has a size and a weight that are at least relatively negligible with respect to a size and a weight of the article.

14. The system of Claim 13, wherein:

the article is a document; and

each of the diodes is embedded in a paper of the document.

15. The system of Claim 10, wherein:

the first high-frequency signal has a first frequency of approximately 24.0 GHz;

the second high-frequency signal has second frequency of approximately 24.1 GHz; and

each of the diodes is responsive to the first and second high-frequency signals.

16. The system of Claim 10, wherein the harmonic signal is a third-order intermodulation product of the first and second high-frequency signals.

17. The method of Claim 16, wherein the harmonic signal corresponds to $2F1 - F2$ or $2F2 - F1$, the first high-frequency signal being approximately equal to $F1$, the second high-frequency signal being approximately equal to $F2$.

18. The method of Claim 10, wherein a frequency of the harmonic signal is used to match the harmonic signal to an article signal.

19. A system for identifying an article carrying a diode, the system comprising:

means for generating a first high-frequency signal;

means for generating a second high-frequency signal;

means for receiving one or more harmonic signals generated by one or more diodes carried by the article in response to the one or more diodes receiving the first and second high-frequency signals, each of the one or more diodes being responsive to high-frequency signals and being carried by an article;

means for communicating the one or more received harmonic signals for matching to an article type; and

means for matching the harmonic signal to an article type to identify the article.