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(54) METHOD FOR OPERATING A TESTING DEVICE FOR TESTING A DISTANCE SENSOR OPERATING WITH ELECTROMAGNETIC WAVES, AND CORRESPONDING TESTING DEVICE

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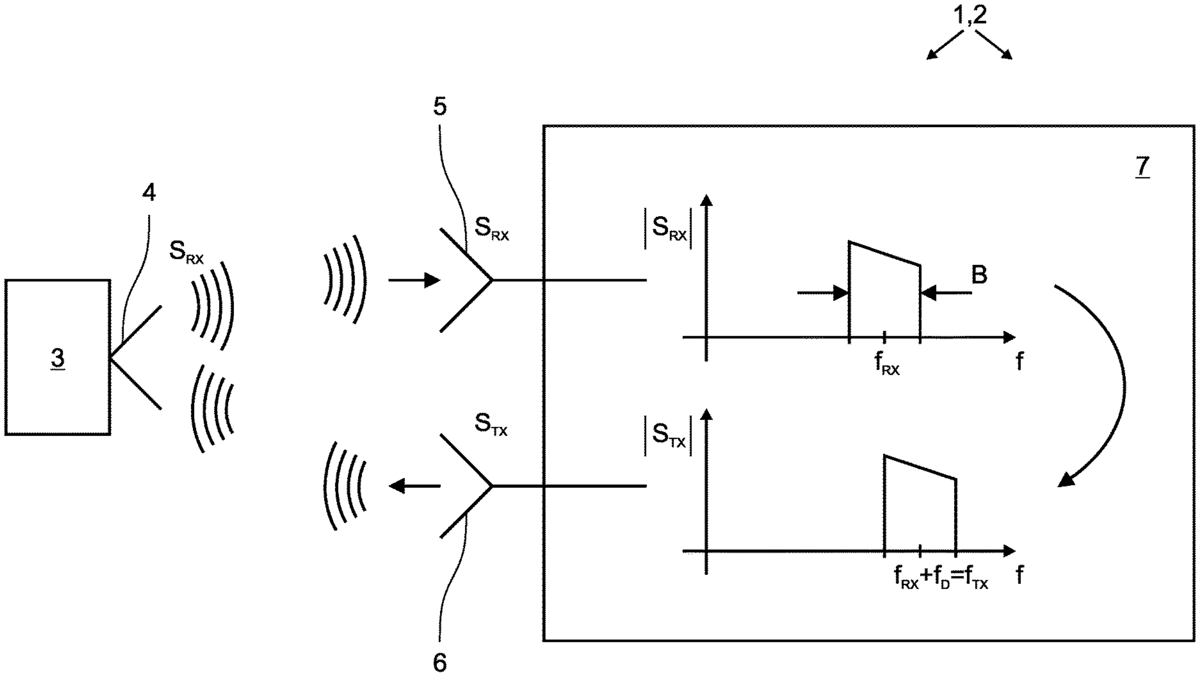
(57) ABSTRACT

A method for testing a distance sensor includes: receiving an electromagnetic free-space wave as a receive signal; generating a simulated electromagnetic reflection signal therefrom; shifting a reflection frequency of the reflection signal by a Doppler frequency smaller than a signal bandwidth of the receive signal; converting the receive signal into a first work signal having a first work frequency smaller than a receive frequency of the receive signal; converting the first work signal into a second work signal having a second work frequency, wherein the difference between the first and second work frequencies is at least as large as the signal bandwidth plus the Doppler frequency; converting the second work signal into a third work signal having a third work frequency that corresponds to the first work frequency shifted by the Doppler frequency; increasing the third work signal by the conversion frequency; and radiating the third work signal.



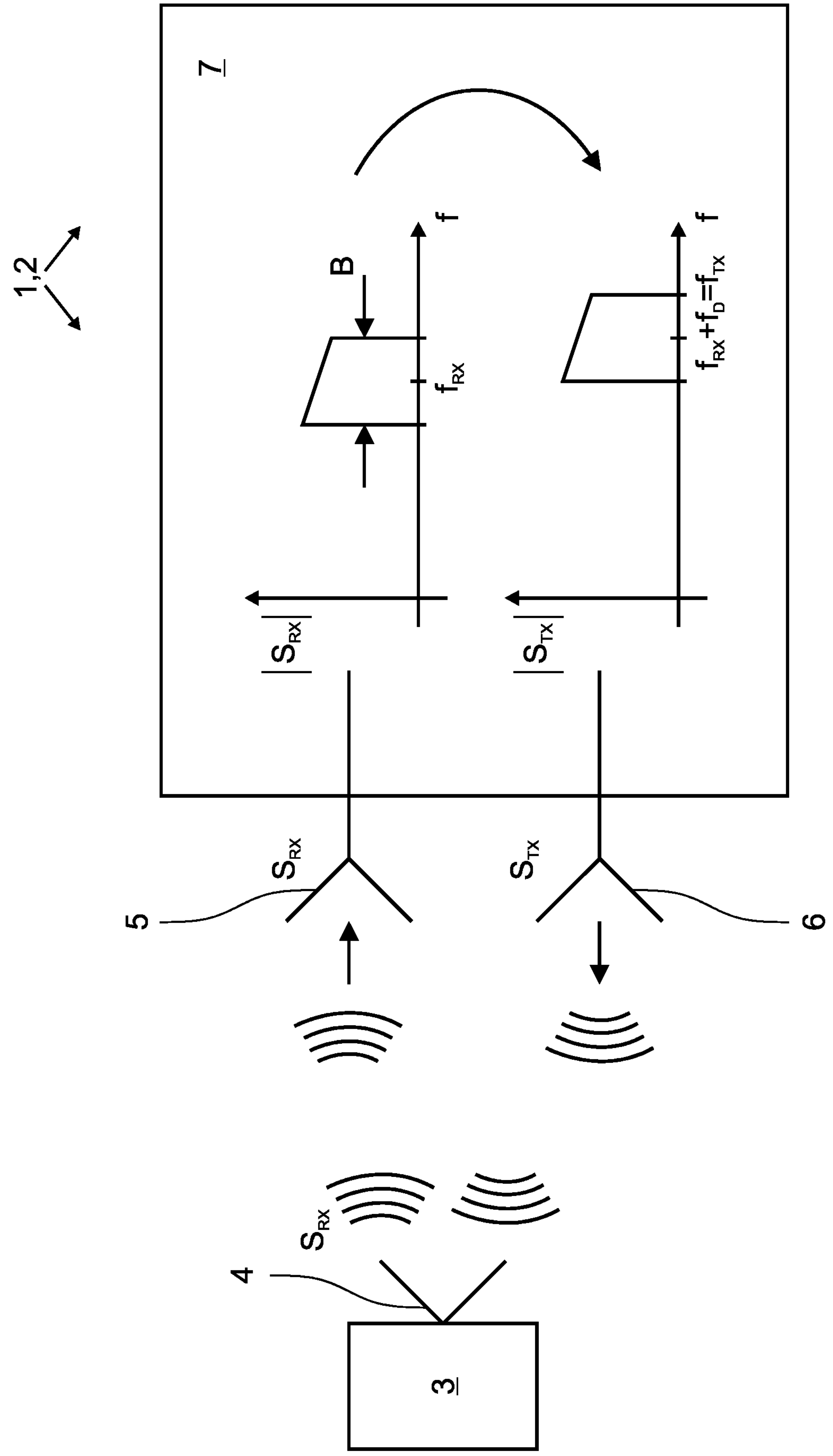


Fig. 1

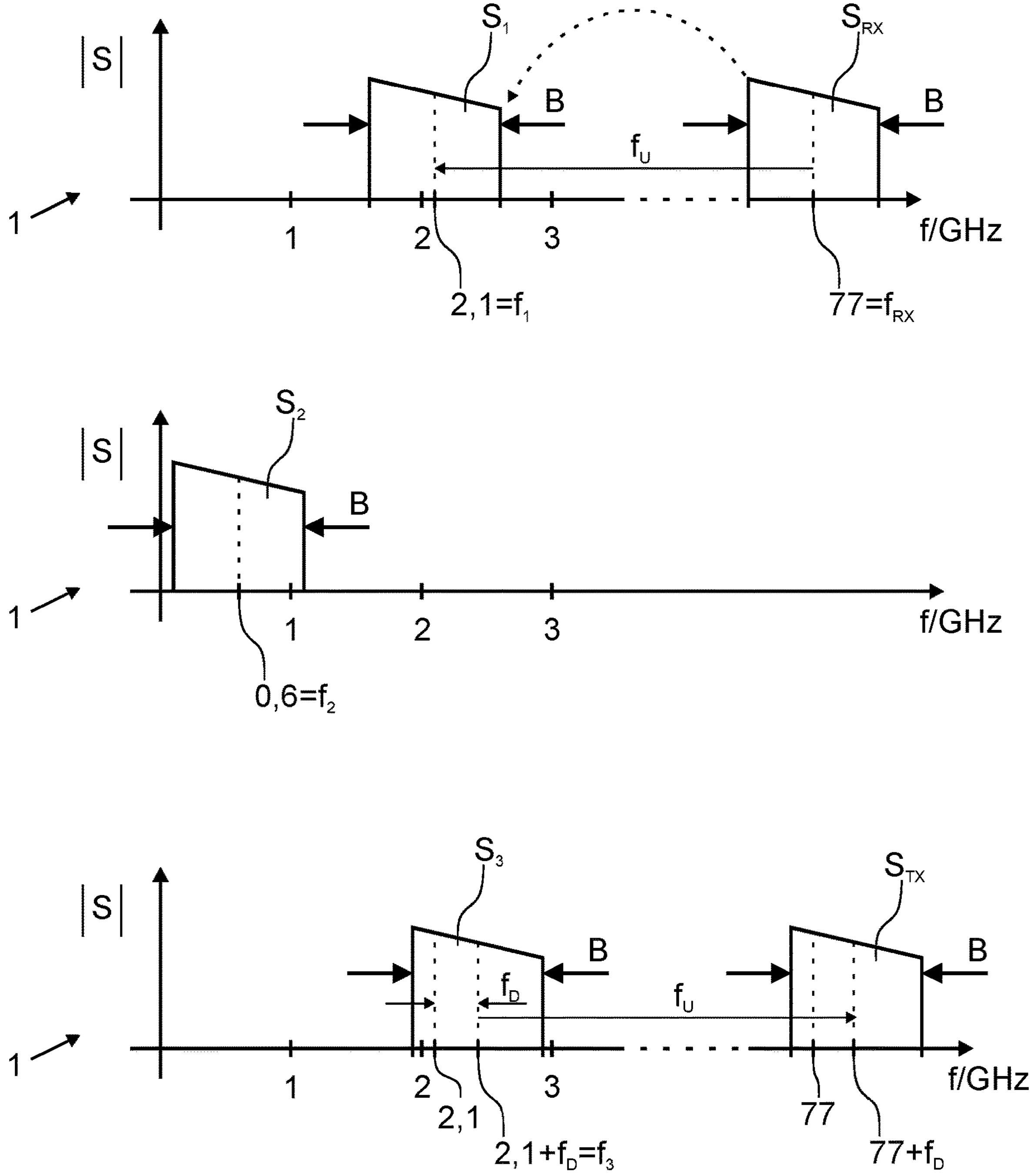

|S|
S_1
S_{RX}
B
B
f_U
1
1
2
3
f/GHz
2,1=f_1
77=f_{RX}
|S|
S_2
B
1
1
2
3
f/GHz
0,6=f_2
|S|
S_3
S_{TX}
B
B
f_D
f_U
1
1
2
3
f/GHz
2,1
2,1+f_D=f_3
77
77+f_D

Fig. 2

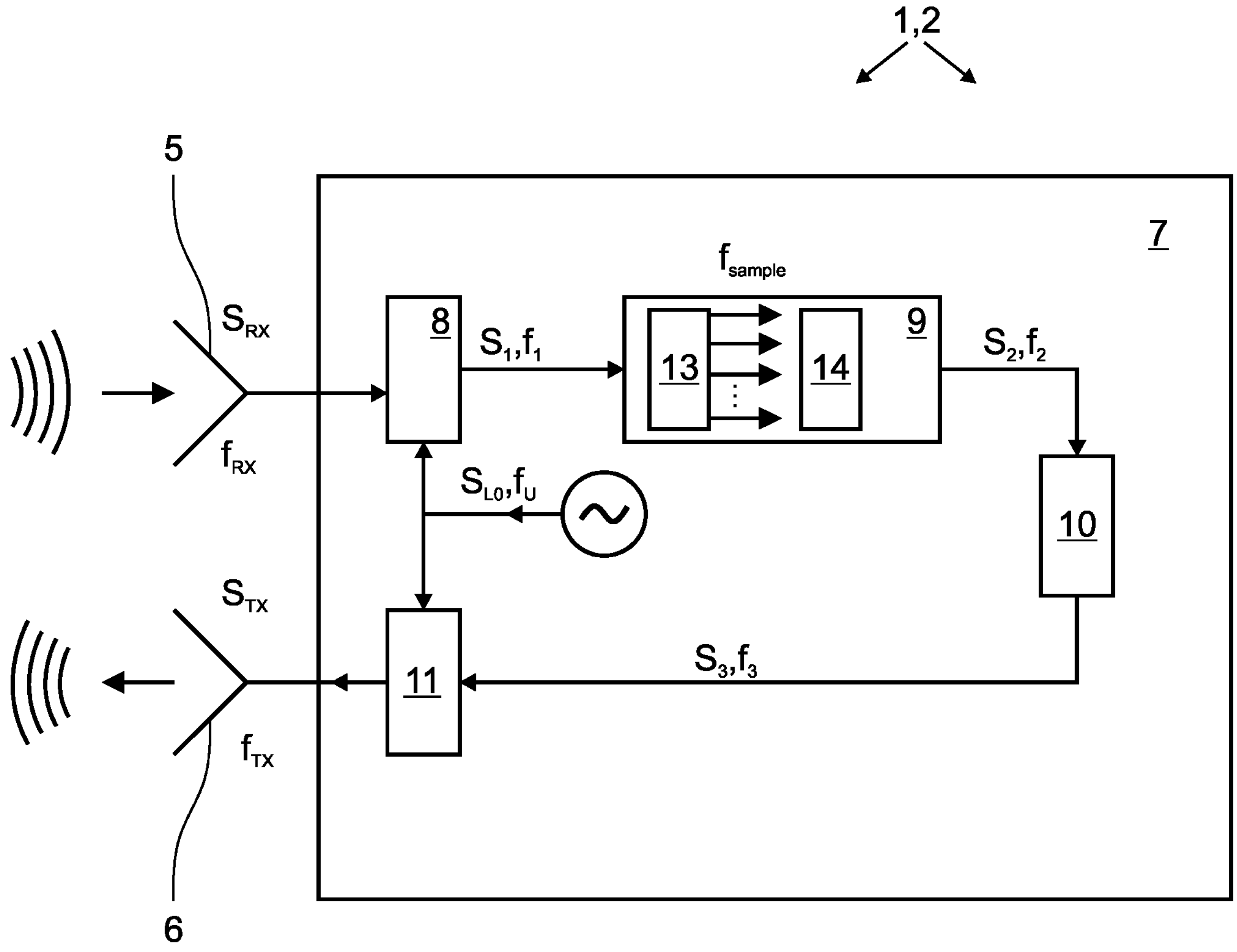

1,2
5
S_{RX}
f_{RX}
S_{TX}
f_{TX}
6
7
8
S_1,f_1
f_{sample}
13
14
9
S_2,f_2
10
S_{L0},f_U
11
S_3,f_3

Fig. 3

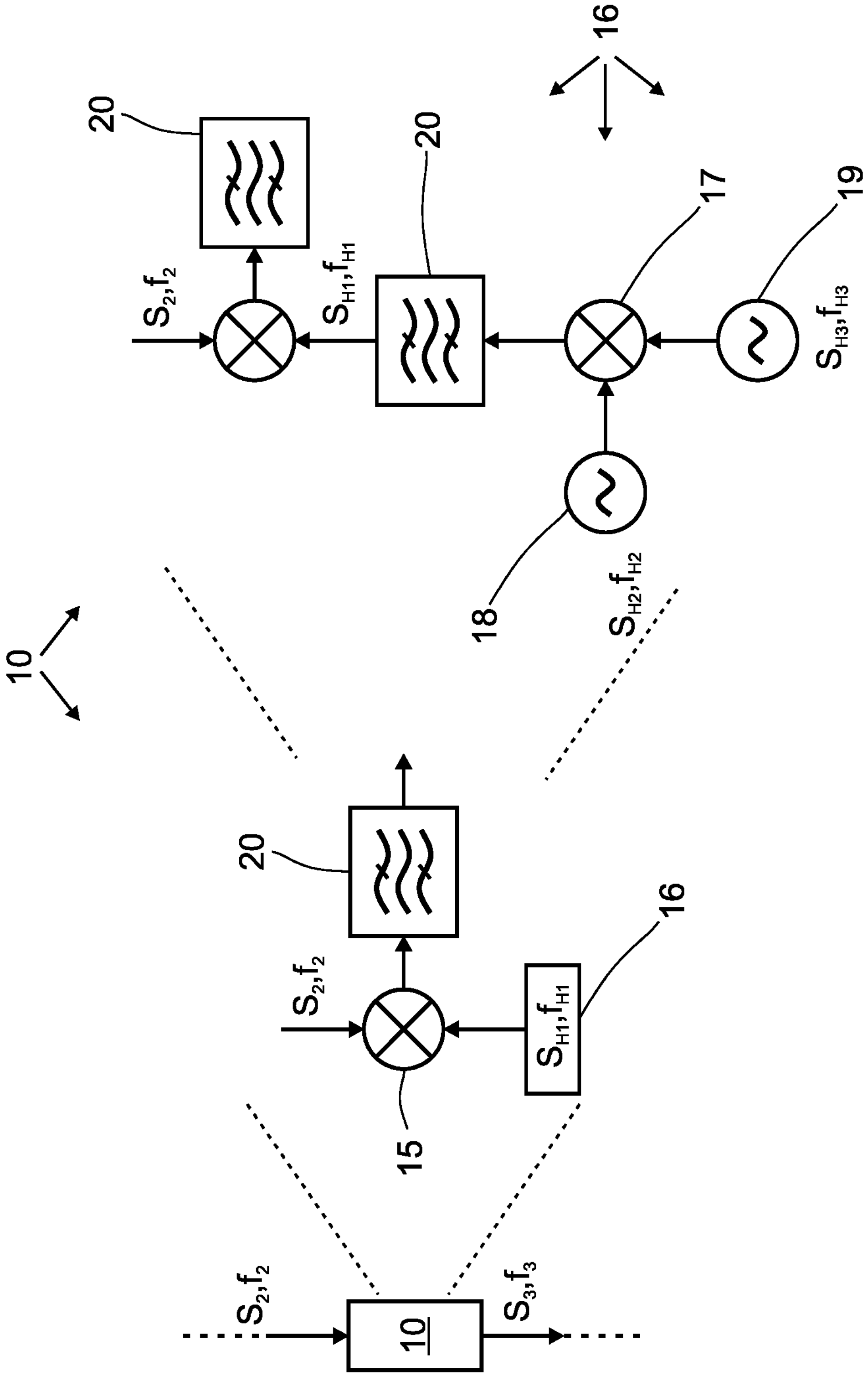

16
20
20
17
19
S2,f2
SH1,fH1
SH3,fH3
18
SH2,fH2
10
20
S2,f2
15
16
SH1,fH1
10
S2,f2
S3,f3

Fig. 4

METHOD FOR OPERATING A TESTING DEVICE FOR TESTING A DISTANCE SENSOR OPERATING WITH ELECTROMAGNETIC WAVES, AND CORRESPONDING TESTING DEVICE

TECHNICAL FIELD

[0001] The invention relates to a method for operating a testing device for testing a distance sensor operating with electromagnetic waves, namely for generating and radiating a simulated electromagnetic reflection signal S_{TX} having a reflection frequency f_{TX}, wherein an electromagnetic free-space wave is received as a receive signal S_{RX} having a receive frequency f_{RX} and a signal bandwidth B and wherein the reflection signal S_{TX} is generated from the received electromagnetic signal S_{RX}, wherein the reflection frequency f_{TX} is shifted by a Doppler frequency f_D relative to the receive frequency f_{RX}, wherein the Doppler frequency f_D is smaller than the signal bandwidth B of the receive signal S_{RX}. Furthermore, the invention also relates to a corresponding testing device, i.e., a testing device for testing a distance sensor operating with electromagnetic waves for carrying out the above method having a receiving element for receiving an electromagnetic free-space wave as a receive signal S_{RX} having a receive frequency f_{RX} and a signal bandwidth B, having a radiating element for radiating a simulated electromagnetic reflection signal S_{TX} having a reflection frequency f_{TX}, wherein signal electronics generate the reflection signal S_{TX} from the electromagnetic receive signal S_{RX}, wherein the signal electronics generate the reflection signal S_{TX} having a reflection frequency f_{TX} shifted by a Doppler frequency f_D to be simulated with respect to the receive frequency f_{RX} of the receive signal S_{RX}, wherein the Doppler frequency f_D is smaller than the signal bandwidth B of the receive signal S_{RX}.

BACKGROUND

[0002] The aforementioned method for operating a testing device and corresponding testing devices for testing distance sensors have been known for some time in the field of control unit development and control unit testing for example in the automotive sector. A frequent test scenario here is to test the functionality of a production control unit using a simulated environment. For this, the environment of the control unit is calculated in part or completely in real time using a powerful simulation environment, wherein the simulation environment generates physical signals that are input signals of the control unit and wherein the simulation environment records the output signals generated by the control unit and incorporates them into the real-time simulation. This allows control units to be tested safely in a simulated environment under virtually “real” conditions. How realistic the test is depends on the quality of the simulation environment and the simulation calculated using it. Control units can thus be tested in a closed loop, which is why such test scenarios are also referred to as hardware-in-the-loop tests.

[0003] The present case deals with the testing of distance sensors that work with electromagnetic waves. In the automotive sector, radar sensors are predominantly used. In principle, however, distance sensors can also be tested that operate in a different frequency range of electromagnetic waves, for example in the visible light range, or that operate with electromagnetic radiation sources that emit electromagnetic waves with a long coherence length, such as in laser applications (e.g., lidar).

[0004] Distance sensors are increasingly being used in modern vehicles to provide the vehicle and its assistance systems with environment information. For example, the position and speed of objects in the vehicle environment are determined. Assistance systems that use such environment information include adaptive cruise control (ACC) and autonomous emergency breaking (AEB). It is understandable that the testing of such safety-relevant assistance systems must be carried out with great care, wherein the propagation behavior of the electromagnetic waves must also be taken into account as realistically as possible. In the past, this was mainly done by very costly and time-consuming real driving tests. These driving tests are increasingly being replaced by the testing devices described above for testing a distance sensor, also known as test benches, in which free space waves are also used. Such test benches are also called OTA test benches (over-the-air), in which the distance sensor to be tested actually radiates electromagnetic waves into the free space, i.e., unguided, and also receives electromagnetic waves from the free space as a simulated reflection signal. The advantage of such OTA test benches is the extensive testing of the entire effect chain in connection with the distance sensor to be tested, including the radiation and reception behavior in which the sensor radiating element and the sensor receiving element are involved.

[0005] Regardless of which type of electromagnetic wave the distance sensor to be tested uses, the testing of distance sensors places extremely high demands on the required electronic signal processing. Distances of an object in the environment are usually determined directly by the signal propagation time, which reflects the emitted electromagnetic waves to the object and from the object back to the distance sensor. Radial velocity components of objects in the environment are determined by frequency shifts between the radiated electromagnetic wave and the reflected electromagnetic wave (Doppler shift).

[0006] Due to the electromagnetic waves propagating at the speed of light, very short signal propagation times must be resolved here. For example, in order to detect a minimum distance of one meter, signal propagation times in the nanosecond range must be resolved. If larger distances are to be measured in the range of centimeters, i.e., independent of the question of minimum distance, it must also be possible to resolve differences in propagation time in the sub-nanosecond range.

[0007] The present invention deals with the simulation of a moving object that moves away from a distance sensor to be tested or moves towards the distance sensor to be tested at a certain radial velocity. These radial motion components are determined by recording the frequency shift of the reflected reflection signal relative to the frequency of the transmitted signal radiated by the distance sensor to be tested; this frequency shift is the Doppler frequency f_D already mentioned at the beginning.

[0008] The electromagnetic waves radiated by the distance sensor to be tested are not actually to be reflected in the test bench or in the test device; rather, the radiated electromagnetic waves are received by a receiving element of the test device and processed in downstream, fast signal electronics—a distance and movement simulator—delayed in running time and frequency modulated. Depending on the distance to be simulated to a simulated environment object or depending on the radial relative velocity of the environment object to the distance sensor to be tested, signals delayed in time and/or frequency shifted by the Doppler frequency are generated by the signal electronics and emitted as a simulated—i.e., not actual—reflection signal via the radiating element of the testing device again in the direction of the distance sensor to be tested. The distance sensor thus creates the impression of a real environment with, if necessary, several objects at different distances and moving at different speeds in the simulated environment.

[0009] Testing devices known from the prior art ("Echte Echos im Labor": dSPACE Magazine 2/2017, December 2017) are characterized by a mechanical test bench structure that will not be discussed here, and by signal electronics for generating a simulated reflection signal, which is what is at issue here, especially the frequency shift of the receive signal by the Doppler frequency f_D. A particular challenge here is that signals with very different frequencies have to be processed together, frequencies that can differ by many orders of magnitude. This is illustrated by a practical example. If, for example, the transmitted signal of the distance sensor to be tested has a (center) frequency of 77 GHz and an object moves radially to the distance sensor at 100 m/s (which corresponds to 360 km/h, a practically already unrealistically high speed in the automotive sector), then the Doppler frequency f_D, i.e., the frequency difference between radiated and received signal, at the distance sensor to be tested is only about 51.55 kHz (first approximation is non-relativistic for small object velocities v compared to the speed of light c and for radiated radar signals with the frequency f_R: $f_D=2*v/c*f_R$, the factor "2" because of the double effect at the point of radiation of the radar radiation, i.e., after reflection). The difference between the frequencies is therefore only in the range of thousandths per mille, with correspondingly high demands on the accuracy of the signal electronics, which for the aforementioned reason is often complex and expensive to implement. If the radar signal itself has a bandwidth of 1 GHz, then the conditions are not much less critical with respect to this value.

SUMMARY

[0010] The object of the present invention is, thus, to design and further develop the method described above for operating a testing device for testing a distance sensor operating with electromagnetic waves and a related testing device in such a manner that it is relatively easy to generate, from a receive signal, a desired reflection signal which is frequency-modulated by a relatively small Doppler frequency relative to the received signal.

[0011] The previously derived and described object is achieved according to the invention in the above-mentioned method for operating a testing device for testing a distance sensor operating with electromagnetic waves in that the receive signal S_{RX}, which the testing device obtains directly from the distance sensor to be tested as a free-space signal, is converted into a first work signal S_1 having a first work frequency f_1, wherein the work frequency f_1 is smaller, by a conversion frequency f_U, than the receive frequency f_{RX} of the receive signal S_{RX}. This means that the signal electronics can operate internally at a considerably lower frequency than the frequency of the receive signal S_{RX}. It makes sense to implement a large frequency jump f_U here. If, for example, the receive signal S_{RX} has a frequency f_{RX} of 77 GHz, then the conversion should ideally take place in the range below 10 GHz.

[0012] In addition, the first work signal S_1 is converted into a second work signal S_2 having a second work frequency f_2 (thus, the second work signal S_2 exhibits the second work frequency f_2), wherein the absolute value of the difference between the first work frequency f_1 and the second work frequency f_2 is at least as large as the signal bandwidth B, preferably at least as large as the sum of the signal bandwidth B and the Doppler frequency f_D. The importance of this measure only becomes clear in connection with the subsequent process step. Here it is provided that the second work signal S_2 is converted into a third work signal S_3 having a third work frequency f_3, the third work signal S_3 thus exhibits this third work frequency f_3. The third work frequency f_3 corresponds to the first work frequency f_1 shifted by the Doppler frequency f_D.

[0013] Finally, this third work signal S_3 is increased by the conversion frequency f_U and thus converted into the reflection signal S_{RX} and radiated. The conversion frequency f_U is the same conversion frequency f_U with which the receive signal S_{RX} was frequency-reduced into a first work signal S_1 in the introduction. The reduction of the receive signal S_{RX} into the first work signal S_1 having the conversion frequency f_U and the increase of the third work signal having the same conversion frequency f_U, on the one hand, opens up interesting possibilities in terms of circuitry for the implementation of the method presented here. On the other hand, boundary conditions are thereby defined, which influence the conversion of the first work signal S_1 into the second work signal S_2 and the conversion of the second work signal S_2 into the third work signal S_3.

[0014] It was mentioned in the introduction that the receive signal S_{RX} has a receive frequency f_{RX} and a signal bandwidth B. This means that the frequency spectrum of the signal has a center frequency f_{RX} and that amplitudes not equal to 0 extend symmetrically to the left and right, i.e., towards smaller frequencies and towards larger frequencies, namely having the signal bandwidth B. The signal bandwidth is the center frequency f_{RX} of the signal. The frequency spectrum therefore extends B/2 to the left of the center frequency f_{RX} and B/2 to the right of the center frequency f_{RX}. The other signals discussed here are also to be understood in the same way.

[0015] In a further development of the method, it is provided that the conversion of the receive signal S_{RX} into the first work signal S_1 is carried out by mixing the receive signal S_{RX} with a local oscillator signal S_{LO} of the conversion frequency f_U. During mixing, the receive signal S_{RX} is converted in its center frequency position, i.e., in dependence on the conversion frequency f_U of the local oscillator signal Sup. Preferably for example with a multiplicative mixing only a mixed-down signal is received, in that a suitable low-pass or bandpass filter is used.

[0016] Another advantage is that the conversion of the third work signal S_3 into the reflection signal S_{TX} is achieved by mixing the third work signal S_3 with a local oscillator signal S_{LO} of the conversion frequency f_U. This is advantageous in connection with the simultaneous mixing-up of the receive signal S_{RX} into the first work signal S_1. In this case, it is provided that both the mixing-down and the mixing-up with the local oscillator signal S_{LO} of the conversion frequency f_U uses an identical local oscillator signal S_{LO}, which is generated by a single local oscillator. This solution is very easy and cost-effective to implement.

[0017] A further advantageous implementation of the method is characterized in that the first work signal S_1 is converted into the second work signal S_2 by time-discrete sampling of the work signal S_1 at a sampling frequency f_{sample} and subsequent digital-to-analog conversion of the sampled work signal S_1 into an analog work signal S_2. This method step takes advantage of the fact that periodically repeating frequency bands are formed in the frequency spectrum of the sampled signal when a signal is sampled in a time-discrete manner, and that time-discrete sampling is therefore suitable for frequency shifting a signal. If the first work signal S_1 exhibits the first work frequency f_1 and the frequency spectrum of the signal also has a signal bandwidth B, then this band repeats in the sampled signal in the intervals $f_1+/-n*f_{sample}$ with n={ . . . ; −3; −2; −1; 0; 1; 2; 3; . . . }. It should be taken into account that the negative frequency band of the sampled signal must also be continued periodically, i.e., also starting from the negative first work frequency $-f_1$. Preferably, then, the second work signal S_2 is only further considered when having a work frequency f_2 lower than the first work frequency f_1 of the first work signal S_1.

[0018] Since the first work frequency f_1 of the first work signal S_1 is already smaller—possibly much smaller—than the receive frequency f_{RX} of the receive signal, correspondingly slower analog-to-digital converters or digital-to-analog converters can be used for the analog-to-digital conversions or for the corresponding digital-to-analog conversions of the sampled work signal S_1, overall the data rates to be managed are thus considerably reduced.

[0019] According to an advantageous design, the sampling frequency f_{sample} should be greater than the signal bandwidth B of the receive signal S_{RX}. This measure ensures that the periodically repeating bands of the sampled first work signal do not overlap in the frequency spectrum, which is a pre-requisite for a flawless reconstruction of the sampled signal. According to a further advantageous design, it is provided that the first work signal S_1 is sub-sampled, f_{sample} is thus smaller than twice the greatest frequency in the spectrum of the first work signal S_1. With this design, aliasing or folding can result in components in the frequency spectrum of the sampled signal that are smaller in frequency than the frequencies of the sampled signal. However, this mostly undesirable effect can be used specifically and is often referred to as digital down conversion (DDC). With the knowledge that the low-frequency aliasing band or folding band is only a low-frequency image of the higher-frequency signal, the sampled signal can be perfectly reconstructed from a lower-frequency aliasing band or a lower-frequency folding band.

[0020] It is provided in one implementation that the second work signal S_2 and the third work signal S_3 are converted by means of mixing with a first auxiliary signal S_{H1} having a frequency f_{H1}. Advantageously, the frequency f_{H1} of the first auxiliary signal S_{H1} then corresponds to the sum frequency of the frequency f_1 of the first work signal S_1, the frequency f_2 of the second work signal S_2 and the Doppler frequency f_D or the negative Doppler frequency $-f_D$. Here, it already becomes apparent that if such a first auxiliary signal S_{H1} is mixed-down with the second work signal S_2 having the second work frequency f_2, a third work signal S_3 results which as desired has the frequency $f_1+/-f_D$. If this work signal S_3 is now mixed-up with the conversion frequency f_U, a reflection signal results having the desired reflection frequency f_{TX}, which corresponds to the frequency f_{RX} of the receive signal S_{RX}, but is increased (radially approaching object) or decreased (radially moving-away object) by the Doppler frequency f_D.

[0021] The presented method can be implemented quite simply and inexpensively with mostly analog circuit technology, in particular when generating the third work signal S_3 from the second work signal S_2, in which the Doppler frequency f_D to be simulated is introduced using signals.

[0022] The described object is achieved with the testing device for testing a distance sensor operating with electromagnetic waves described in the introduction by providing appropriate means that make it possible to carry out the method described above using the testing device, wherein the means are specifically designed in such a manner that the testing device carries out the method described above during operation. In particular, this means that the receive signal S_{RX} is converted by a first converter into a first work signal S_1 having a first work frequency f_1, wherein the work frequency f_1 is smaller, by a conversion frequency f_U, than the receive frequency f_{RX} of the receive signal S_{RX}, that the first work signal S_1 is converted by a second converter into a second work signal S_2 having a second work frequency f_2, wherein the absolute value of the difference between the first work frequency f_1 and the second work frequency f_2 is at least as large as the signal bandwidth B, preferably at least as large as the sum of the signal bandwidth B and the Doppler frequency f_D, that the second work signal S_2 is converted by a third converter into a third work signal S_3 having a third work frequency f_3, wherein the third work frequency f_3 corresponds to the first work frequency f_1 shifted by the Doppler frequency f_D, and that the third work frequency f_3 corresponds to the first work frequency f_1 shifted by the Doppler frequency f_D and that the third work signal S_3 is increased by the conversion frequency f_U using a fourth converter and is thus converted into the reflection signal S_{RX} and radiated.

BRIEF DESCRIPTION OF THE DRAWINGS

[0023] In detail, there is now a plurality of possibilities for designing and further developing the method according to the invention for operating a testing device for testing a distance sensor operating with electromagnetic waves and a related testing device. For this, reference is made to the following description of embodiments in conjunction with the drawings.

[0024] FIG. **1** illustrates a method known from the prior art for operating a testing device for testing a distance sensor operating with electromagnetic waves and such a testing device.

[0025] FIG. **2** illustrates a method according to the invention with frequency spectra of different signals.

[0026] FIG. **3** illustrates a method and a device according to the invention with a schematic signal flow diagram.

[0027] FIG. **4** illustrates a more detailed representation of the third converter in analog technology.

DETAILED DESCRIPTION

[0028] FIG. **1** shows a method **1** for operating a testing device **2** for testing a distance sensor **3** operating with electromagnetic waves and also a corresponding testing device **2**. The method **1** and testing device **2** are used for testing the distance sensor **3**, which, in this case, is a distance sensor **3** operating with radar waves. The distance sensor **3** has a transmitting and receiving device **4** for radiating radar signals and for receiving radar signals which have been reflected by an object in actual use. In the shown test situation, there is no actual object, but only the testing device **2** with the implemented method **1** for the simulation of an actual object in view of the distance sensor **3** to be tested. The method **1** and the testing device **2** are used for the generation and radiation of a simulated electromagnetic reflection signal S_{TX} having a reflection frequency f_{TX}.

[0029] The electromagnetic wave radiated by the distance sensor **3** is received as an electromagnetic free-space wave as a receive signal S_{RX} having a receive frequency f_{RX}. The receive signal S_{RX} also has a signal bandwidth B. This is indicated in FIG. **1** by the uppermost frequency spectrum. The reflection signal S_{TX} is generated from the electromagnetic receive signal S_{RX} in a manner not shown here in detail, wherein the reflection frequency f_{TX} is shifted by a Doppler frequency f_D with respect to the receive frequency f_{RX}, whereby the Doppler frequency f_D is smaller than the signal bandwidth B of the receive signal S_{RX}. This is indicated in the lower part by the second frequency spectrum of FIG. **1**.

[0030] In the present case, the receive signal S_{RX} has a center frequency f_{RX} of 77 GHz and a bandwidth B of 1 GHz. The testing device **2** has a receiving element **5** for receiving the receive signal S_{RX}. The testing device **2** has a radiating element **6** for radiating the simulated electromagnetic reflection signal S_{TX}. In the example shown in FIG. **1**, the receiving element **5** and the radiating element **6** are separate antennas, which need not necessarily be the case, but the receiving element **5** and the radiating element **6** may also be designed as a single common antenna. The testing device **2** comprises signal electronics **7** which generate the reflection signal S_{TX} from the receive signal S_{RX}. How this is carried out in the prior art is not described further here.

[0031] FIG. **2** now shows the method **1**, with which a reflection signal S_{TX} shifted by the Doppler frequency f_D is generated from the receive signal S_{RX}. The method is shown here using frequency spectra in which the various signals involved are represented in terms of frequency. In the uppermost frequency spectrum, it can be seen that the high-frequency receive signal S_{RX} having a receive frequency f_{RX} of 77 GHz is converted into a first work signal S_1 with a first work frequency f_1 of 2.1 GHz. The work frequency f_1 is smaller here, by a conversion frequency f_U, than the receive frequency f_{RX} of the receive signal S_{RX}. This first frequency conversion is carried out in order to be able to work in a smaller frequency range that is easier to handle in terms of circuitry. It has been recognized that a direct conversion of the receive signal S_{RX}; into the reflection signal S_{TX} is not possible, since the desired frequency offset around the Doppler frequency f_D is extremely small compared to the bandwidth B of the receive signal S_{RX}. A direct mixing of the receive signal S_{RX} with a signal having the Doppler frequency f_D or a time-discrete sampling of the receive signal S_{RX} with a sampling rate f_{sample} that is much smaller than the bandwidth of the receive signal S_{RX} would lead to overlapping spectra in the frequency spectrum, so that the reflection signal S_{TX} would no longer be a single-frequency, shifted receive signal S_{RX}, but a completely different signal.

[0032] It is useful to look at FIG. **3** in parallel to FIG. **2**, which, in addition to the signal course of the method **1**, also simultaneously, schematically depicts the testing device **2**. In FIG. **3**, the means by which the various method steps in FIG. **2** are carried out are also shown here. For example, FIG. **3** shows that the receive signal S_{RX} is converted into the first work signal S_1 with a first converter **8**.

[0033] It is now provided and shown in FIG. **2** in the medium frequency spectrum that the first work signal S_1 is converted into a second work signal S_2 having a second work frequency f_2, wherein the absolute value of the difference between the first work frequency f_1 and the second work frequency f_2 is at least as great as the signal bandwidth B. This ensures that no overlapping bands occur in the frequency spectrum. In the present case, the second work frequency f_2 of the second work signal is selected to be 0.6 GHz. The distance between the spectra is sufficiently large with the above-mentioned requirement of being able to manage without collisions of any frequency bands that might occur during the subsequent frequency shift of the second work signal S_2. The first work signal S_1 is converted into the second work signal S_2 by a second converter **9** (FIG. **3**).

[0034] In a further step, it is now provided that the second work signal S_2 is converted into a third work signal S_3 having a third work frequency f_3, wherein the third work frequency f_3 corresponds to the first work frequency f_1 shifted by the Doppler frequency f_D. In the example shown, the Doppler frequency f_D has been added to the first work frequency f_1, which corresponds to an approaching of an object to be simulated. Equally, the third work signal S_3 could also be shifted in the other direction toward the first work frequency f_1, i.e., towards lower frequencies, which corresponds to an object moving away. Since the third work frequency f_3 was selected in dependence on the first work frequency f_1, the third work signal S_3 can now be increased by the conversion frequency f_U, i.e., the conversion frequency f_U that was used in the frequency spectrum shown at the top for conversion to a low frequency range, whereby the reflection signal S_{TX} is generated and finally radiated. The second work signal S_2 is converted into the third work signal S_3 with a third converter **10**. Accordingly, the third work signal S_3 is increased by the conversion frequency f_U with a fourth converter **11**, whereby the reflection signal S_{TX} is generated and radiated.

[0035] In the embodiment shown in FIG. **3**, the receive signal S_{RX} is converted into the first work signal S_1 by mixing the receive signal S_{RX} with a local oscillator signal S_{LO} having the conversion frequency f_U. The first converter **8** is therefore designed as a mixer. The local oscillator signal S_{LO} is generated by a first local oscillator **12**.

[0036] When the various signals are converted, the signal bandwidth B is retained in each case. In the embodiment shown (upper frequency spectrum in FIG. **2**), the spectrum of the first work signal S_1 is shifted such that it is spaced from the frequency 0 by more than one signal bandwidth B, because the smallest frequency of the spectrum of the first work signal S_1 is 1.6 GHz. This plays a role in connection with the present embodiment (middle frequency spectrum in FIG. **2**), since the second work frequency f_2 of the second work signal S_2 is smaller than the first work frequency f_1 of the first work signal S_1.

[0037] The clever selection of the work frequency f_3 of the third work signal enables that the conversion of the third work signal S_3 into the reflection signal S_{TX} is achieved by mixing the third work signal S_3 with the same local oscillator signal S_{LO} of the conversion frequency f_U. Consequently, the fourth converter **11** is designed as a mixer and is supplied with the local oscillator signal S_{LO} generated by the first local oscillator **12**. This makes the circuit design simple, since one and the same mix signal S_{LO} can be used for input-side mixing-down of the receive signal and output-side mixing-up of the third work signal S_3 to generate the reflection signal S_{RX}.

[0038] As already mentioned, the second work frequency f_2 of the second work signal S_2 generated by the second converter **9** is smaller than the first work frequency f_1 of the first work signal S_1; this is possible without problems because sufficient distance to the zero frequency was left during the generation of the first work signal S_1.

[0039] As indicated in FIG. **3**, the first work signal S_1 and the second work signal S_2 are converted by time-discrete sampling of the work signal S_1 having a sampling frequency f_{sample}. Subsequent digital-to-analog conversion of the sampled work signal S_1 produces an analog work signal S_2. This is achieved by converting the first work signal S_1 into the second work signal S_2 with an analog-to-digital converter **13**, which is part of the second converter **9**, by time-discrete sampling of the work signal S_1 having a sampling frequency f_{sample}. Accordingly, the second converter **9** also comprises a digital-to-analog converter **14**, which generates an analog work signal S_2 from the sampled work signal S_1. As explained in the general description section, the fact is taken advantage of here that when a signal in the frequency spectrum of the sampled signal is sampled in a time discrete manner, a periodically repeating sequence of the sampled signal occurs, both towards higher frequencies and towards lower frequencies. Since the work signal S_1 has been shifted into a very small frequency range, the analog-to-digital converter **13** and the digital-to-analog converter **14** can operate with relatively low data rates. This also has a positive effect on the comparatively simple design of the testing device **2** and signal electronics **7** of the testing device **2**. In another embodiment, the second converter **9** is designed as a digital signal processor (DSP), with which a corresponding analog-to-digital conversion or digital-to-analog conversion is implemented. In the embodiment shown, the sampling frequency f_{sample} is greater than the signal bandwidth B of the receive signal S_{RX}, which prevents the frequency bands in the frequency spectrum (not shown here in detail) from overlapping periodically, so that the sampled signal can be reconstructed perfectly. In the embodiment shown, the first work signal S_1 is sub-sampled by the second converter **9**. The sampling frequency f_{sample} is implemented with 2.7 GHz and therefore smaller than twice the greatest frequency in the spectrum of the first work signal S_1, the largest frequency here being 2.6 GHz. This subsampling results in frequency bands in a lower frequency range. Knowing that these frequency bands actually correspond to a higher frequency in the sampled signal, a perfect reconstruction of the sampled signal is also possible using the lower frequency band (digital down conversion).

[0040] In the embodiment shown, it is implemented that the sampling frequency f_{sample} of the analog-to-digital converter **13** contained in the second converter **9** is greater than the greatest frequency in the spectrum of the first work signal S_1, i.e., greater than 2.6 GHz. At the selected sampling frequency there is so-called folding, which leads to a reflection of the sampled frequency band (inverse position, see middle frequency spectrum in FIG. **2**).

[0041] The Doppler frequency f_D is introduced in the third converter **10**. The configuration of the third converter **10** as well as the method implemented in it are shown in detail in a signal flow diagram in FIG. **4**. In FIG. **4**, the degree of detail of the illustration increases from left to right. The middle figure shows that the second work signal S_2 is converted into the third work signal S_3 by mixing with a first auxiliary signal S_{H1} having a frequency f_{H1}. The third converter **10** is therefore essentially designed as a mixer or comprises such a mixer **15** as a central element. The first auxiliary signal S_{H1} is generated by an auxiliary signal generator **16**.

[0042] The frequency f_{H1} of the first auxiliary signal S_{H1} generated by the auxiliary signal generator **16** corresponds to the sum frequency of the frequency f_1 of the first work signal S_1, the frequency f_2 of the second work signal S_2 and the Doppler frequency f_D or the negative Doppler frequency $-f_D$. Thus, a frequency shift of the receive signal S_{RX} to a frequency increased by the Doppler frequency f_D as well as to a frequency reduced by the Doppler frequency f_D can be implemented. FIG. **4** also shows that the first auxiliary signal SH, is generated by the auxiliary signal generator **16** by mixing a second auxiliary signal S_{H2} having the frequency f_{H2} and a third auxiliary signal S_{H3} having the frequency f_{H3} with an auxiliary signal mixer **17**. The frequency f_{H2} corresponds to the sum frequency of the frequency f_1 of the first work signal S_{H1} and the Doppler frequency f_D. The frequency f_{H3} of the third auxiliary signal S_{H3} corresponds to the Doppler frequency f_D. The auxiliary signal generator **16** comprises a local oscillator **18** with a fixed frequency and a tunable oscillator **19** with a tunable frequency. The second auxiliary signal S_{H2} is therefore generated by the local oscillator **18** having a fixed frequency and the third auxiliary signal S_{H3} is generated by the tunable oscillator **19** having a tunable frequency. This tunable frequency is the Doppler frequency f_D by which the receive signal S_{RX} is to be shifted. The Doppler frequency f_D is usually given by an environment simulation and changes constantly with the constantly changing driving situation simulated by an environment simulator.

[0043] As can be seen in particular from the illustration in FIG. **4**, the signals generated are—at least partially—filtered out of an entire spectrum by means of a suitable bandpass filter **20** or by means of a suitable low-pass filter.

[0044] Here, it is implemented that after mixing the second auxiliary signal S_{H2} with the third auxiliary signal S_{H3} by means of the auxiliary signal mixer **17**, a very narrow-band bandpass filter **20** is used to filter out one of the two resulting mixed signals; the present mixed signal has the frequency $f_1+f_2+f_D$, as can be seen from the bottom illustration in FIG. **3**.

1. A method for operating a testing device for testing a distance sensor operating with electromagnetic waves, comprising:

receiving an electromagnetic free-space wave as a receive signal having a receive frequency and a signal bandwidth;

generating a simulated electromagnetic reflection signal from the received electromagnetic signal;

shifting a reflection frequency of the reflection signal by a Doppler frequency relative to the receive frequency, wherein the Doppler frequency is smaller than the signal bandwidth of the receive signal;

converting the receive signal into a first work signal having a first work frequency, wherein the work frequency is smaller, by a conversion frequency, than the receive frequency of the receive signal;

converting the first work signal into a second work signal having a second work frequency, wherein the absolute value of the difference between the first work frequency and the second work frequency is at least as large as the signal bandwidth;

converting the second work signal into a third work signal having a third work frequency, wherein the third work frequency corresponds to the first work frequency shifted by the Doppler frequency;

increasing the third work signal by the conversion frequency and, thus, converting the third work signal into the reflection signal; and

radiating the third work signal.

2. The method according to claim **1**, wherein the conversion of the receive signal into the first work signal is carried out by mixing the receive signal with a local oscillator signal of the conversion frequency.

3. The method according to claim **1**, wherein a spectrum of the first work signal having a signal bandwidth is spaced from the frequency zero at least by the signal bandwidth.

4. The method according to claim **1**, wherein the conversion of the third work signal into the reflection signal is achieved by mixing the third work signal with a local oscillator signal of the conversion frequency.

5. The method according to claim **4**, wherein the local oscillator signal of the conversion frequency for mixing the receive signal and for mixing the third work signal is an identical local oscillator signal generated by a single local oscillator.

6. The method according to claim **1**, wherein the second work frequency of the second work signal is smaller than the first work frequency of the first work signal.

7. The method according to claim **1**, wherein the first work signal-St is converted into the second work signal by time-discrete sampling of the work signal at a sampling frequency and subsequent digital-to-analog conversion of the sampled work signal into an analog work signal.

8. The method according to claim **7**, wherein the sampling frequency is greater than the signal bandwidth-s of the receive signal and that the first work signal is sub-sampled, thus, the sampling frequency is smaller than twice the greatest frequency in the spectrum of the first work signal.

9. The method according to claim **8**, wherein the sampling frequency is greater than the greatest frequency in the spectrum of the first work signal-St.

10. The method according to claim **1**, wherein the second work signal is converted into the third work signal by mixing with a first auxiliary signal having a frequency.

11. The method (**1**) according to claim **10**, a first frequency of the first auxiliary signal corresponds to the sum frequency of the frequency of the first work signal, the frequency of the second work signal and the Doppler frequency.

12. The method according to claim **10**, wherein the first auxiliary signal is generated by mixing a second auxiliary signal having a second frequency and a third auxiliary signal having a third frequency; and

wherein the second frequency corresponds to the sum frequency of the frequency of the first work signal and the frequency of the second work signal; and

wherein the third frequency corresponds to the Doppler frequency.

13. The method according to claim **12**, wherein the second auxiliary signal is generated by a local oscillator having a fixed frequency and the third auxiliary signal having tunable frequency is generated by a tunable oscillator.

14. The method according to claim **1**, wherein at least one of the generated signals is filtered out of a total spectrum by means of a suitable bandpass filter or by means of a suitable low-pass filter after a mixing operation.

15. The method according to claim **14**, wherein, after mixing the second auxiliary signal with the third auxiliary signal, a very narrow-band band filter is used in order to filter out one of the two resulting mixed signals.

16. A testing device for testing a distance sensor operating with electromagnetic waves, comprising:

a receiving element for receiving an electromagnetic free-space wave as a receive signal having a receive frequency and a signal bandwidth;

a radiating element for radiating a simulated electromagnetic reflection signal having a reflection frequency;

signal electronics configured to generate the reflection signal from the electromagnetic receive signal, the reflection signal having a reflection frequency shifted by a Doppler frequency to be simulated with respect to the receive frequency of the receive signal, wherein the Doppler frequency is smaller than the signal bandwidth of the receive signal;

a first converter configured to convert the receive signal into a first work signal having a first work frequency, wherein the work frequency is smaller, by a conversion frequency, than the receive frequency of the receive signal,

a second converter configured to convert the first work signal into a second work signal having a second work frequency, wherein the absolute value of the difference between the first work frequency and the second work frequency is at least as large as the signal bandwidth;

a third converter configured to convert the second work signal into a third work signal having a third work frequency, wherein the third work frequency corresponds to the first work frequency shifted by the Doppler frequency, wherein the third work frequency corresponds to the first work frequency shifted by the Doppler frequency; and

a fourth converter configured to increase the third work signal by the conversion frequency and thus convert the third work signal into the reflection signal and radiate the third work signal.

17. The testing device according to claim **16**, wherein the conversion of the receive signal into the first work signal is carried out by means of a first converter designed as a mixer by mixing the receive signal with a local oscillator signal of the conversion frequency generated by a first local oscillator.

18. The testing device according to claim **16**, wherein a spectrum of the first work signal generated by the first converter having a signal bandwidth is spaced from the frequency zero at least by the signal bandwidth.

19. The testing device according to claim **16**, wherein the conversion of the third work signal into the reflection signal is achieved by the fourth converter, which is designed as a mixer, by mixing the third work signal with the local oscillator signal of the conversion frequency generated by the first local oscillator.

20. The testing device according to claim **16**, wherein the second work frequency of the second work signal generated by the second converter is smaller than the first work frequency of the first work signal.

21. The testing device according to claim **16**, wherein the first work signal is converted into the second work signal with an analog-to-digital converter contained in the second converter by time-discrete sampling of the work signal having a sampling frequency and subsequent digital-to-analog conversion of the sampled work signal into an analog work signal with a digital-to-analog converter contained in the second converter.

22. The testing device according to claim **21**, wherein the sampling frequency of the analog-to-digital converter contained in the second converter is greater than the signal bandwidth of the receive signal, and the first work signal is sub-sampled, thus, is smaller than twice the greatest frequency in the spectrum of the first work signal.

23. The testing device according to claim **22**, wherein the sampling frequency of the analog-to-digital converter contained in the second converter is greater than the greatest frequency in the spectrum of the first work signal.

24. The testing device according to claim **16**, wherein the second work signal is converted into the third work signal by the third converter in the form of a mixer by mixing with a first auxiliary signaler having a first frequency generated by an auxiliary signal generator.

25. The testing device according to claim **24**, wherein the first frequency of the first auxiliary signal generated by the auxiliary signal generator corresponds to the sum frequency of the frequency of the first work signal, the frequency of the second work signal and the Doppler frequency.

26. The testing device according to claim **24**, wherein the first auxiliary signal is generated by the auxiliary signal generator by mixing a second auxiliary signal having a second frequency and a third auxiliary signal having a third frequency with an auxiliary signal mixer, wherein the frequency corresponds to the sum frequency of the first frequency of the first work signal and the second frequency of the second work signal and wherein the third frequency corresponds to the Doppler frequency.

27. The testing device according to claim **26**, wherein the auxiliary signal generator includes a local oscillator with a fixed frequency and a tunable oscillator with a tunable frequency, and that the second auxiliary signal is generated by the local oscillator having a fixed frequency and the third auxiliary signal having a tunable frequency is generated by the tunable oscillator.

28. The testing device according to claim **16**, wherein at least one of the generated signals is filtered out of a total spectrum by means of a suitable bandpass filter or by means of a suitable low-pass filter carried out after a mixing operation.

29. The testing device according to claim **28**, wherein, after mixing the second auxiliary signal with the third auxiliary signal by means of the auxiliary signal mixer, a very narrow-band bandpass filter is used to filter out one of the two resulting mixed signals.

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