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(54) **APPARATUS, METHOD, AND COMPUTER PROGRAM**

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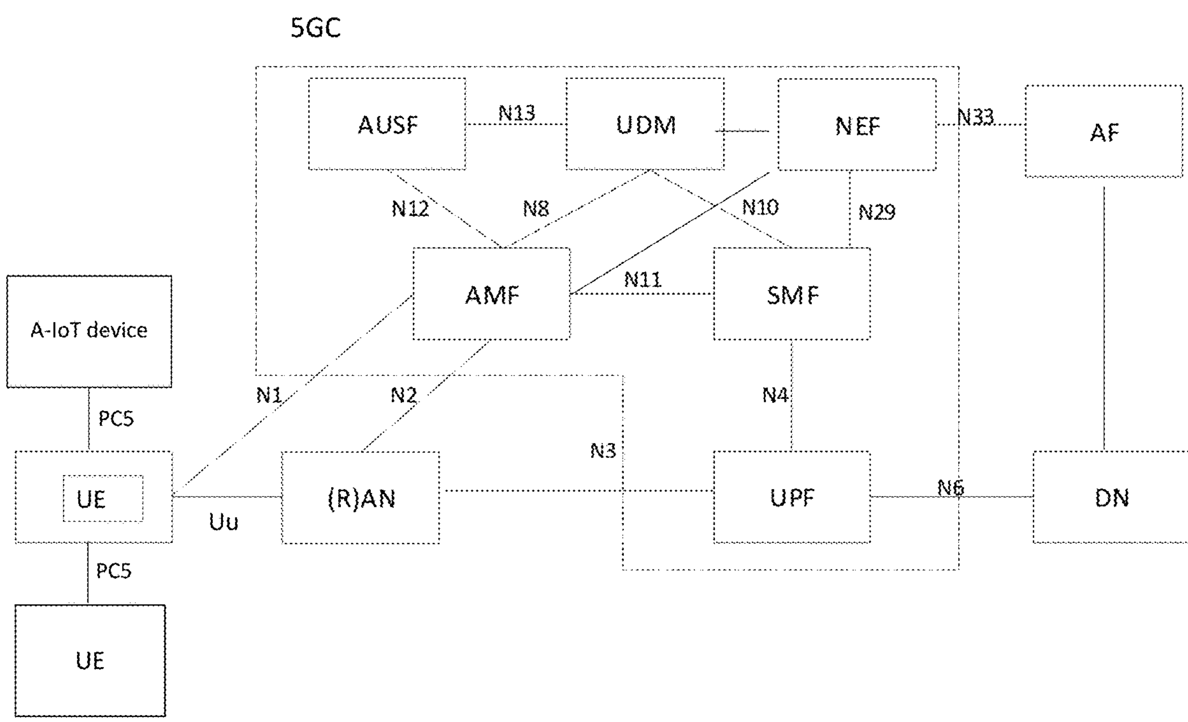
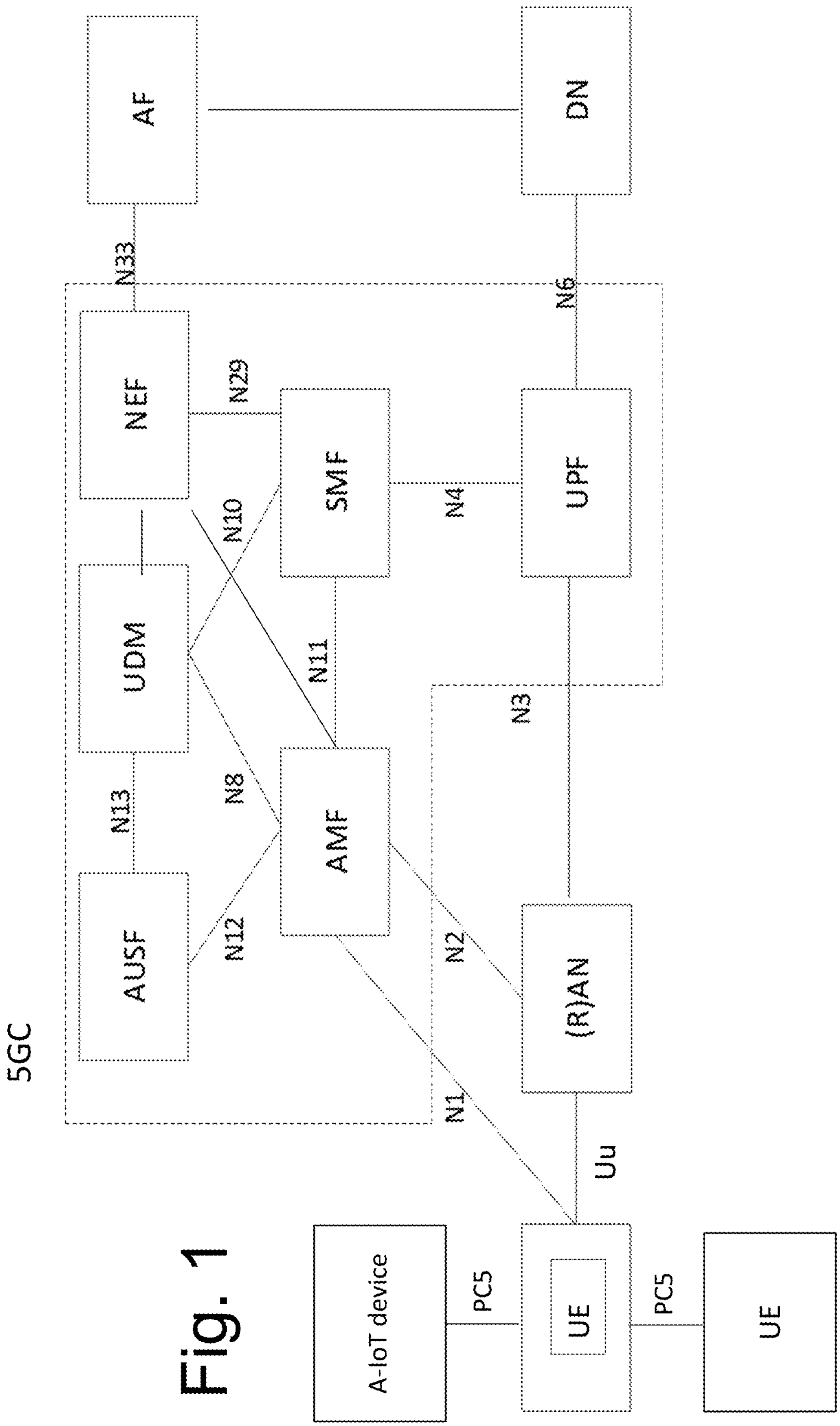
(57) **ABSTRACT**

The disclosure relates to an apparatus configured to: receive, from a device, a response signal to an activation signal over a channel; generate a first vector in a time domain including samples of the response signal; perform a transformation of the first vector in the time domain to obtain a second vector y_i in a frequency domain including pilot symbols and data symbols; estimate a channel response H_i of the channel based on the pilot symbols; equalize the data symbols based on the channel response H_i; determine a waveform of the response signal, from among a plurality of waveforms the apparatus is configurable to handle, based on configuration information; and process the equalized data symbols based on the determined waveform.




5GC
AUSF
UDM
NEF
AF
AMF
SMF
UPF
DN
(R)AN
UE
UE
UE
A-IoT device
N1
N2
N3
N4
N6
N8
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N11
N12
N13
N29
N33
Uu
PC5
PC5

Fig. 1

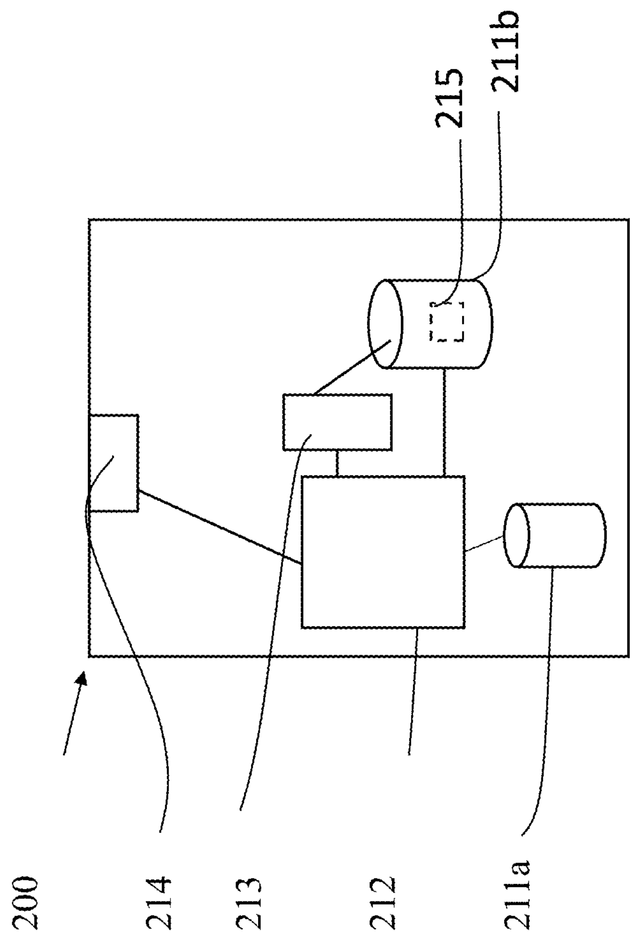

Fig. 2

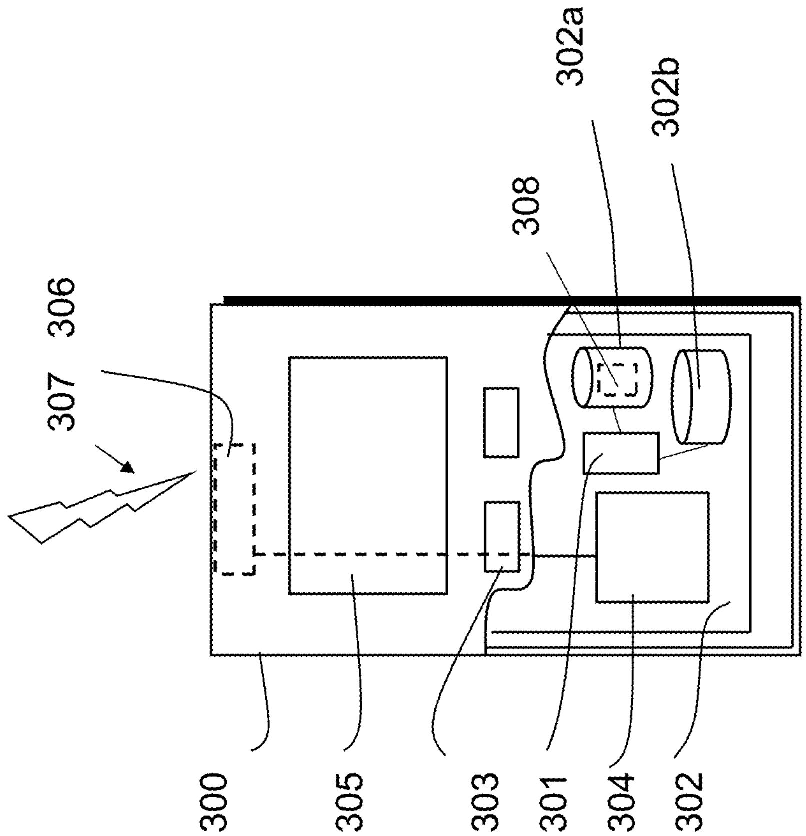

Fig. 3

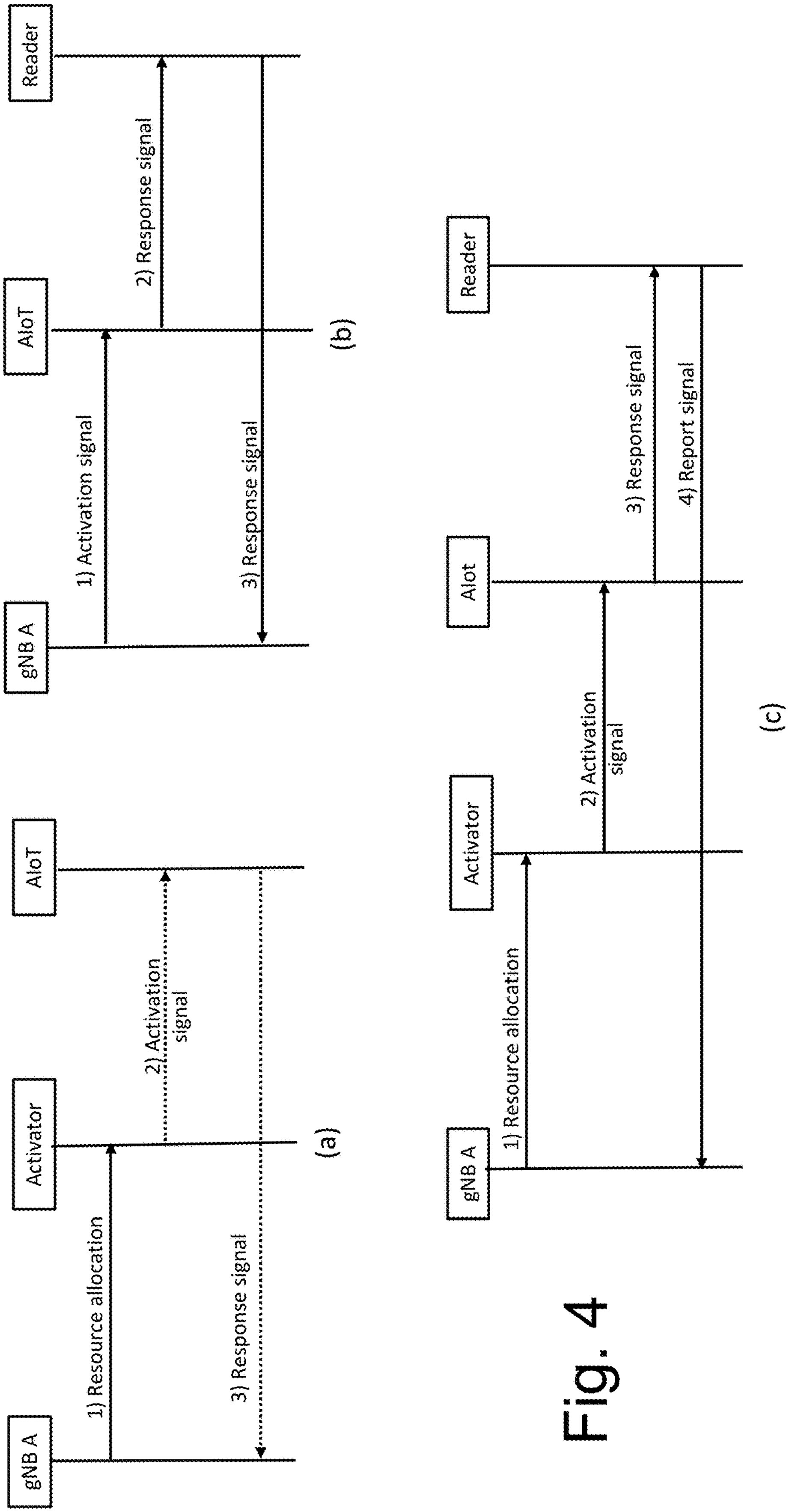
gNB A
Activator
AIoT
1) Resource allocation
2) Activation signal
3) Response signal
(a)
gNB A
AIoT
Reader
1) Activation signal
2) Response signal
3) Response signal
(b)
gNB A
Activator
AIot
Reader
1) Resource allocation
2) Activation signal
3) Response signal
4) Report signal
(c)

Fig. 4

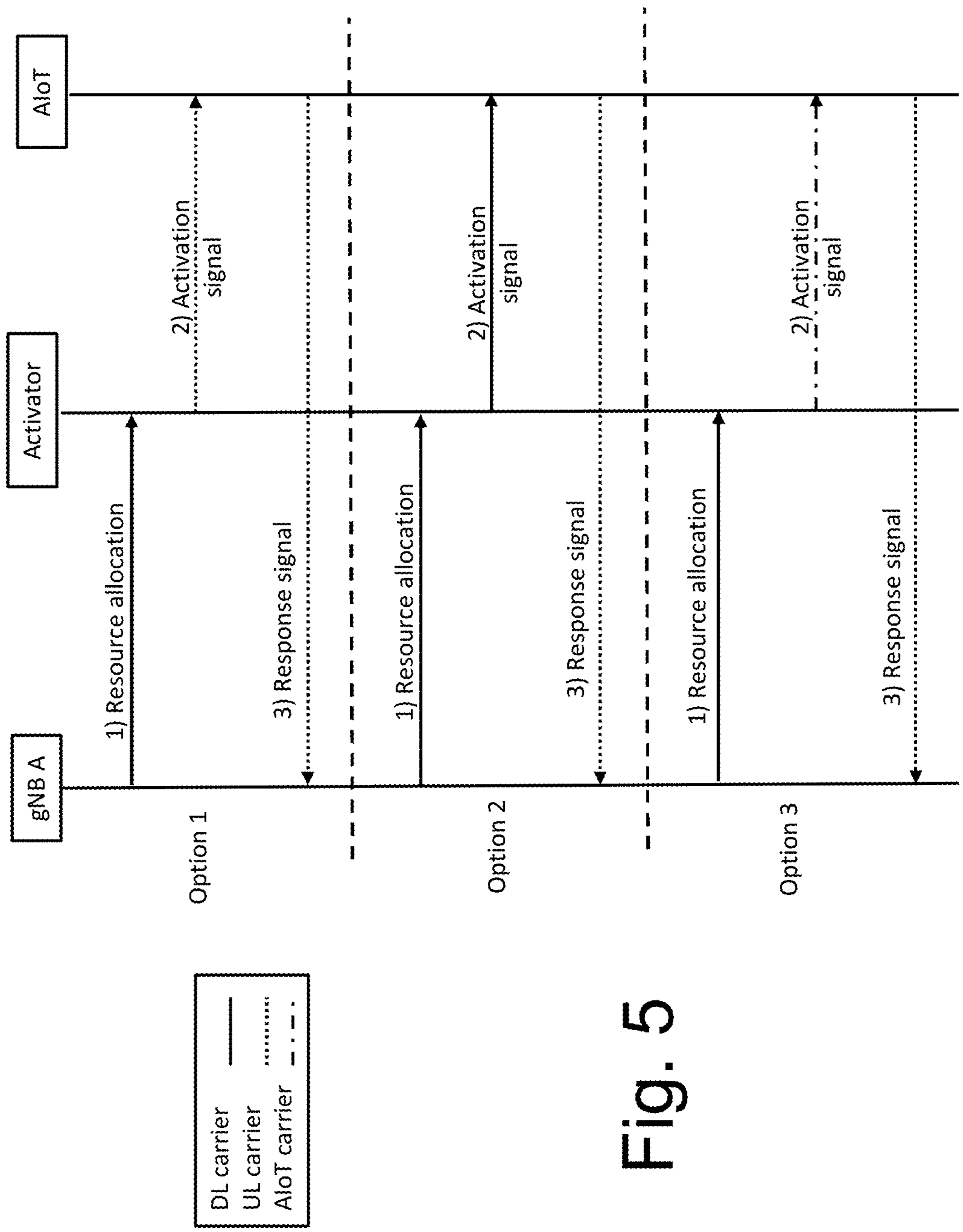
gNB A
Activator
AIoT
Option 1
1) Resource allocation
2) Activation signal
3) Response signal
Option 2
1) Resource allocation
2) Activation signal
3) Response signal
Option 3
1) Resource allocation
2) Activation signal
3) Response signal
DL carrier
UL carrier
AIoT carrier

Fig. 5

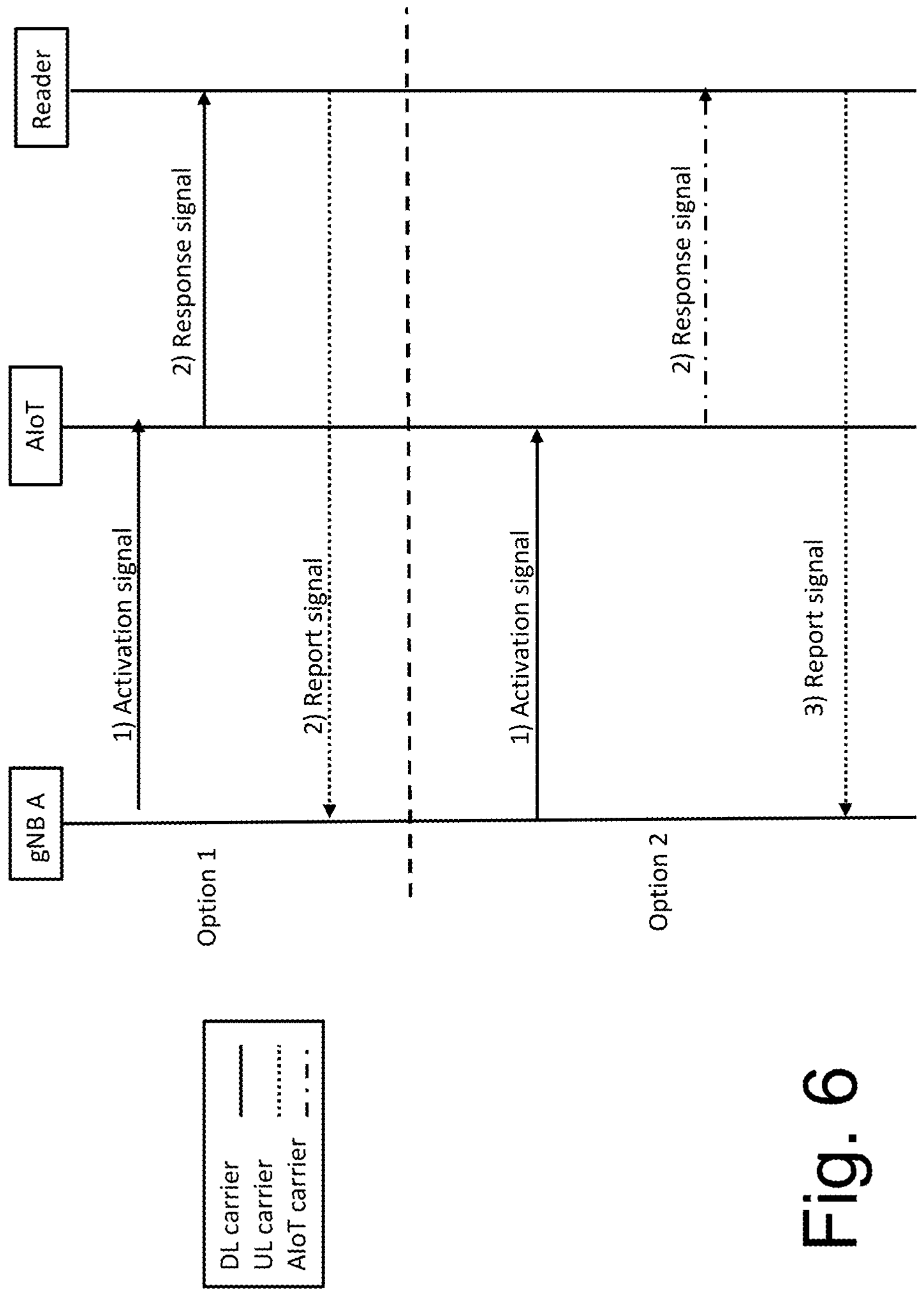
Reader
AIoT
gNB A
1) Activation signal
2) Response signal
2) Report signal
Option 1
1) Activation signal
2) Response signal
3) Report signal
Option 2
DL carrier
UL carrier
AIoT carrier

Fig. 6

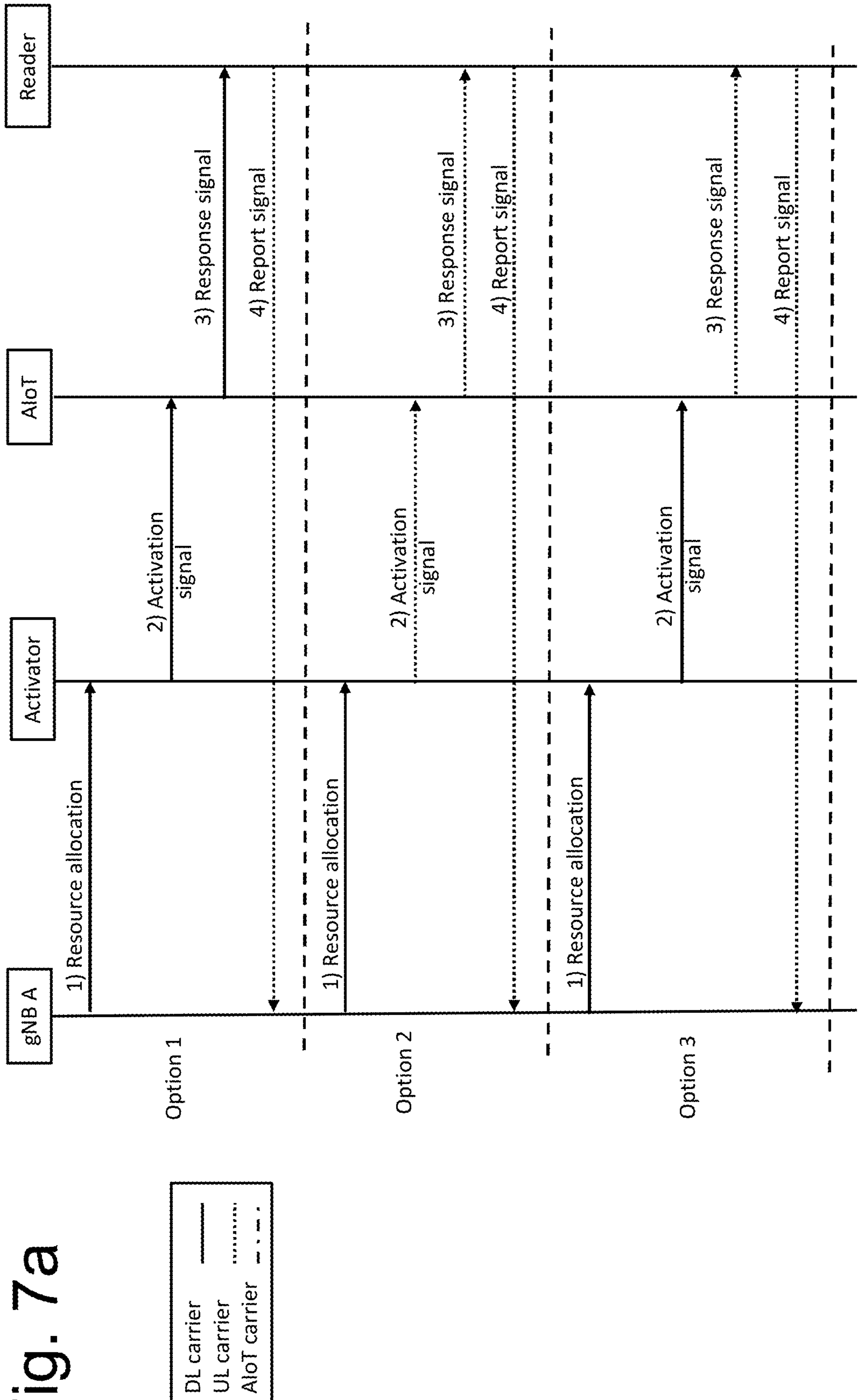
gNB A
Activator
AIoT
Reader
1) Resource allocation
2) Activation signal
3) Response signal
4) Report signal
Option 1
Option 2
Option 3
DL carrier
UL carrier
AIoT carrier

Fig. 7a

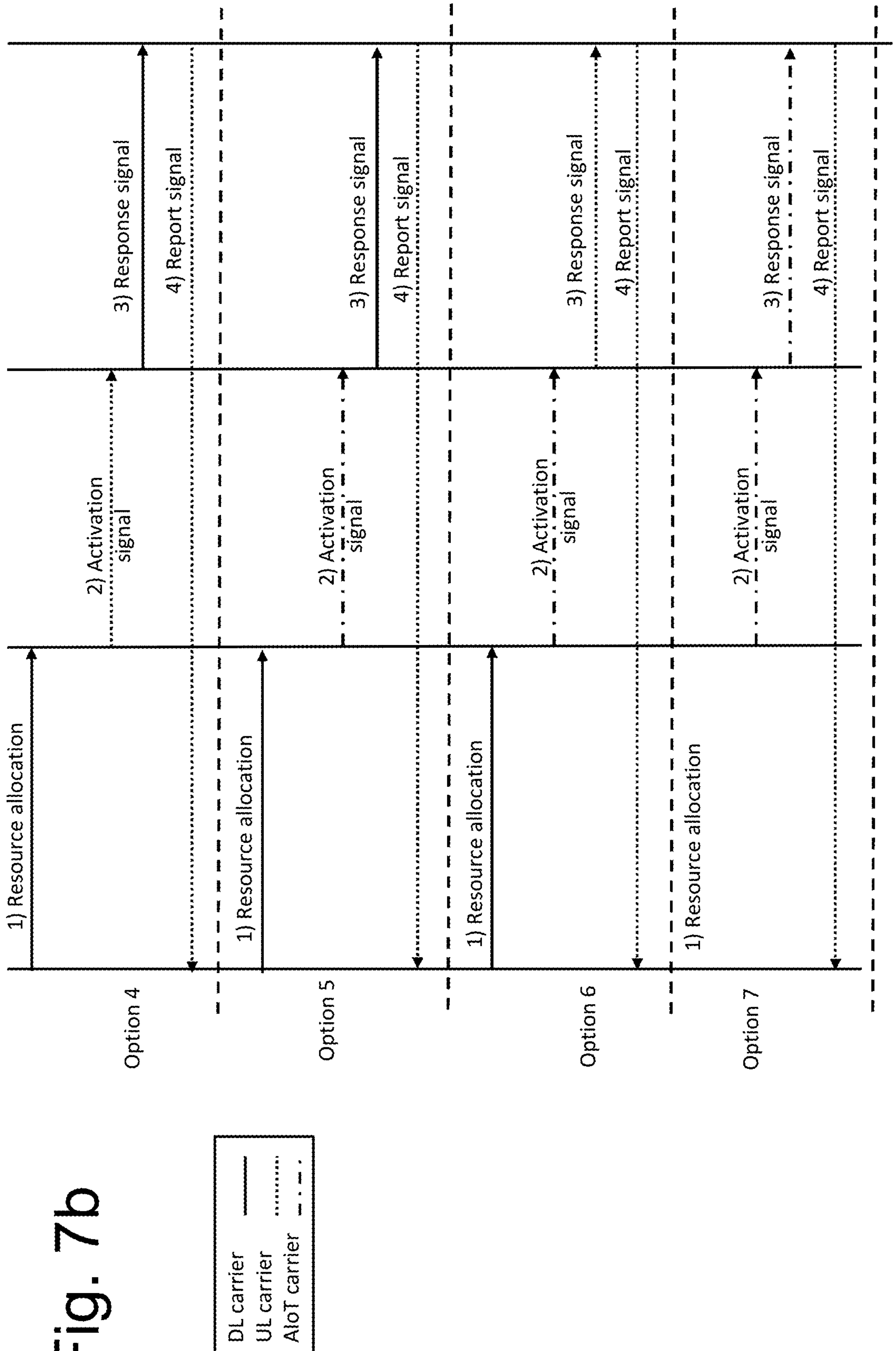
Option 4
Option 5
Option 6
Option 7
1) Resource allocation
2) Activation signal
3) Response signal
4) Report signal
DL carrier
UL carrier
AIoT carrier

Fig. 7b

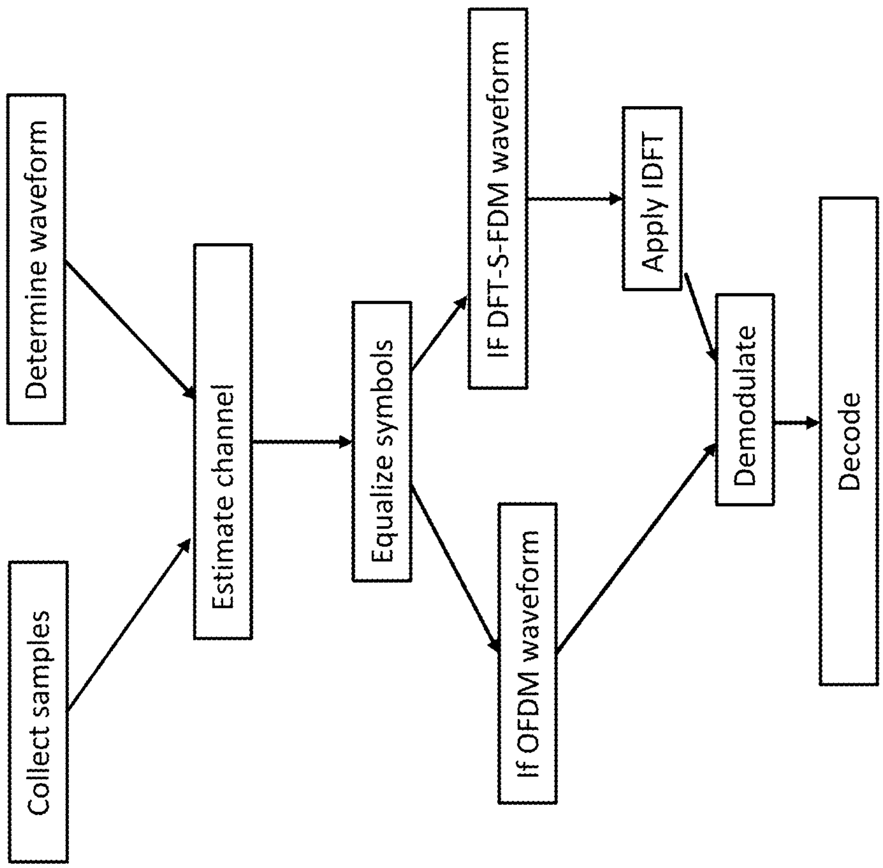
Determine waveform
Collect samples
Estimate channel
Equalize symbols
IF DFT-S-FDM waveform
If OFDM waveform
Apply IDFT
Demodulate
Decode

Fig. 8

900 Apparatus may receive, from a base station, control information comprising an indication of a first frequency resource for transmitting, to a device, an activation signal and an indication of a second frequency resource for transmitting, to a reader, a response signal, wherein the first frequency resource is at least partially different from the second frequency resource

↓

902 Apparatus may transmit, to the device, the activation signal on the first frequency resource, wherein the activation signal comprises the indication of the second frequency resource for transmitting, to the reader, the response signal

Fig. 9

1000 Apparatus may determine a first frequency resource for transmitting, to a device, an activation signal and a second frequency resource for transmitting, to a reader, a response signal, wherein the first frequency resource is at least partially different from the second frequency resource

Fig. 10

1100 Apparatus may receive, from a base station, downlink control information comprising: a FRIV including an indication of a first frequency resource for transmitting, to a device, an activation signal and an indication of a second frequency resource for transmitting, to a reader, a response signal, wherein the first frequency resource is at least partially different from the second frequency resource; and a TRIV including an indication of a first time resource for transmitting, to the device, the activation signal and an indication of a second time resource for transmitting, to the reader, the response signal, wherein the first time resource is at least partially different from the second time resource

1102 Apparatus may transmit, to the device, the activation signal on the first frequency resource, wherein the activation signal comprises the indication of the second frequency resource for transmitting, to the reader, the response signal

Fig. 11

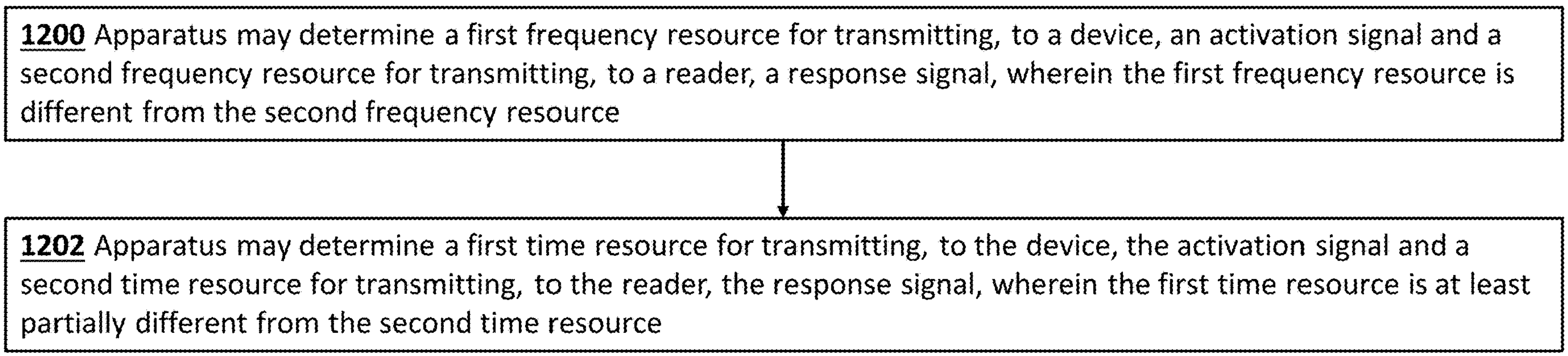
1200 Apparatus may determine a first frequency resource for transmitting, to a device, an activation signal and a second frequency resource for transmitting, to a reader, a response signal, wherein the first frequency resource is different from the second frequency resource
1202 Apparatus may determine a first time resource for transmitting, to the device, the activation signal and a second time resource for transmitting, to the reader, the response signal, wherein the first time resource is at least partially different from the second time resource

Fig. 12

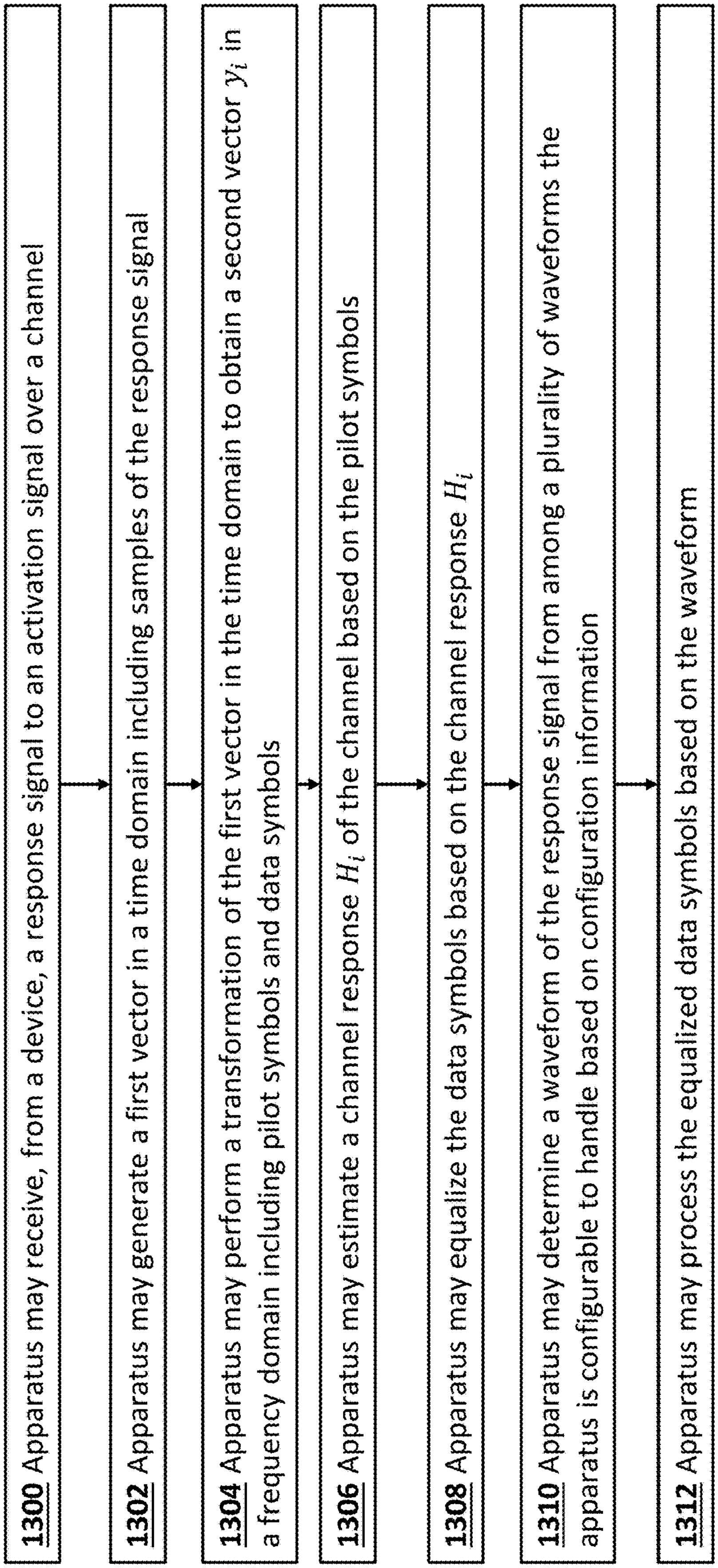
1300 Apparatus may receive, from a device, a response signal to an activation signal over a channel
1302 Apparatus may generate a first vector in a time domain including samples of the response signal
1304 Apparatus may perform a transformation of the first vector in the time domain to obtain a second vector y_i in a frequency domain including pilot symbols and data symbols
1306 Apparatus may estimate a channel response H_i of the channel based on the pilot symbols
1308 Apparatus may equalize the data symbols based on the channel response H_i
1310 Apparatus may determine a waveform of the response signal from among a plurality of waveforms the apparatus is configurable to handle based on configuration information
1312 Apparatus may process the equalized data symbols based on the waveform

Fig. 13

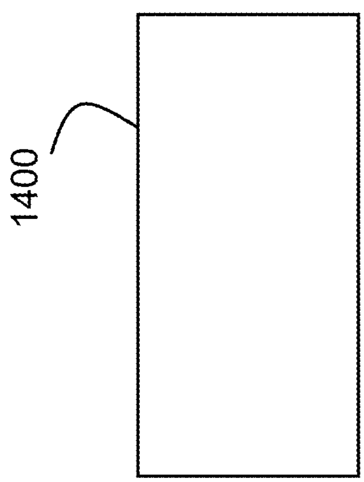

Fig. 14

APPARATUS, METHOD, AND COMPUTER PROGRAM

FIELD OF THE DISCLOSURE

[0001] The present disclosure relates to an apparatus, a method, and a computer program for managing a device (e.g., ambient Internet of things device), in a communication system.

BACKGROUND

[0002] A communication system can be seen as a facility that enables communication sessions between two or more entities such as communication devices, base stations and/or other nodes by providing carriers between the various entities involved in the communications path.

[0003] The communication system may be a wireless communication system. Examples of wireless systems comprise public land mobile networks (PLMN) operating based on radio standards such as those provided by 3GPP, satellite based communication systems and different wireless local networks, for example wireless local area networks (WLAN). The wireless systems can typically be divided into cells, and are therefore often referred to as cellular systems.

[0004] The communication system and associated devices typically operate in accordance with a given standard or specification which sets out what the various entities associated with the system are permitted to do and how that should be achieved. Communication protocols and/or parameters which shall be used for the connection are also typically defined. Examples of standard are the so-called 5G standards.

SUMMARY

[0005] According to an aspect there is provided an apparatus comprising at least one processor and at least one memory storing instructions that, when executed by the at least one processor, cause the apparatus at least to: receive, from a device, a response signal to an activation signal over a channel; generate a first vector in a time domain including samples of the response signal; perform a transformation of the first vector in the time domain to obtain a second vector y_i in a frequency domain including pilot symbols and data symbols; estimate a channel response H_i of the channel based on the pilot symbols; equalize the data symbols based on the channel response H_i; determine a waveform of the response signal, from among a plurality of waveforms the apparatus is configurable to handle, based on configuration information; and process the equalized data symbols based on the determined waveform.

[0006] The activation signal may trigger the device to transmit the response signal.

[0007] The response signal may be dependent on the activation signal. The response signal may be a backscattered (i.e., reflected) modulation of the activation signal.

[0008] The device may be an active device. The response signal may be independent from the activation signal. The response signal may not be a backscattered (i.e., reflected) modulation of the activation signal.

[0009] The pilot symbols may be mapped to pilot subcarriers. The data symbols may be mapped to data subcarriers.

[0010] The at least one memory may store instructions that, when executed by the at least one processor, cause the apparatus at least to: sample the response signal to generate cyclic prefix samples and remaining samples; and delete the cyclic prefix samples; and the first vector may include the remaining samples.

[0011] Determining a waveform of the response signal may comprise: determining that a waveform of the response signal comprise a first waveform; and processing the data symbols based on the determined waveform may comprise: demodulating the equalized data symbols to obtain demodulated and equalized data symbols.

[0012] The first waveform may comprise orthogonal frequency division multiplexing.

[0013] The first waveform may comprise cyclic prefix orthogonal frequency division multiplexing.

[0014] Determining a waveform of the response signal may comprise: determining that a waveform of the response signal is a second waveform; and processing the data symbols based on the determined waveform may comprise: performing an inverse digital Fourier transformation of the equalized data symbols to obtain inverse digital Fourier transformed and equalized data symbols; and demodulating the inverse digital Fourier transformed and equalized data symbols to obtain demodulated, inverse digital Fourier transformed and equalized data symbols.

[0015] The second waveform may comprise digital Fourier transform spread frequency division multiplexing.

[0016] Processing the data symbols based on the determined waveform may comprise: decoding the demodulated and equalized data symbols to obtain data; or decoding the demodulated, inverse digital Fourier transformed and equalized data symbols to obtain data.

[0017] The configuration information may be received from a base station.

[0018] The configuration information may be received from the device.

[0019] The configuration information may comprise an explicit indication of the waveform of the response signal.

[0020] The configuration information may comprise an implicit indication of the waveform of the response signal.

[0021] The implicit indication of the waveform of the response signal may comprise a device type.

[0022] A device type may comprise a device type A, a device type B or a device type C.

[0023] The apparatus may be a reader.

[0024] The reader may be a user equipment.

[0025] The reader may be a base station.

[0026] The transformation may be a digital Fourier transformation.

[0027] The device may be an Internet of things device.

[0028] The device may be a passive device or an active device.

[0029] According to an aspect there is provided an apparatus comprising means for: receiving, from a device, a response signal to an activation signal over a channel; generating a first vector in a time domain including samples of the response signal; performing a transformation of the first vector in the time domain to obtain a second vector y_i in a frequency domain including pilot symbols and data symbols; estimate a channel response H_i of the channel based on the pilot symbols; equalizing the data symbols based on the channel response H_i; determining a waveform of the response signal, from among a plurality of waveforms the apparatus is configurable to handle, based on configuration information; and processing the equalized data symbols based on the determined waveform.

[0030] According to an aspect there is provided an apparatus comprising circuitry configured to: receive, from a device, a response signal to an activation signal over a channel; generate a first vector in a time domain including samples of the response signal; perform a transformation of the first vector in the time domain to obtain a second vector y_i in a frequency domain including pilot symbols and data symbols; estimate a channel response H_i of the channel based on the pilot symbols; equalize the data symbols based on the channel response H_i; determine a waveform of the response signal, from among a plurality of waveforms the apparatus is configurable to handle, based on configuration information; and process the equalized data symbols based on the determined waveform.

[0031] According to an aspect there is provided a method comprising: receiving, from a device, a response signal to an activation signal over a channel; generating a first vector in a time domain including samples of the response signal; performing a transformation of the first vector in the time domain to obtain a second vector y_i in a frequency domain including pilot symbols and data symbols; estimate a channel response H_i of the channel based on the pilot symbols; equalizing the data symbols based on the channel response H_i; determining a waveform of the response signal, from among a plurality of waveforms the apparatus is configurable to handle, based on configuration information; and processing the equalized data symbols based on the determined waveform.

[0032] The method may be performed by an apparatus.

[0033] The activation signal may trigger the device to transmit the response signal.

[0034] The response signal may be dependent on the activation signal. The response signal may be a backscattered (i.e., reflected) modulation of the activation signal.

[0035] The device may be an active device. The response signal may be independent from the activation signal. The response signal may not be a backscattered (i.e., reflected) modulation of the activation signal.

[0036] The pilot symbols may be mapped to pilot subcarriers. The data symbols may be mapped to data subcarriers.

[0037] The method may comprise: sampling the response signal to generate cyclic prefix samples and remaining samples; and deleting the cyclic prefix samples; and the first vector may include the remaining samples.

[0038] Determining a waveform of the response signal may comprise: determining that a waveform of the response signal comprise a first waveform; and processing the data symbols based on the determined waveform may comprise: demodulating the equalized data symbols to obtain demodulated and equalized data symbols.

[0039] The first waveform may comprise orthogonal frequency division multiplexing.

[0040] The first waveform may comprise cyclic prefix orthogonal frequency division multiplexing.

[0041] Determining a waveform of the response signal may comprise: determining that a waveform of the response signal is a second waveform; and processing the data symbols based on the determined waveform may comprise: performing an inverse digital Fourier transformation of the equalized data symbols to obtain inverse digital Fourier transformed and equalized data symbols; and demodulating the inverse digital Fourier transformed and equalized data symbols to obtain demodulated, inverse digital Fourier transformed and equalized data symbols.

[0042] The second waveform may comprise digital Fourier transform spread frequency division multiplexing.

[0043] Processing the data symbols based on the determined waveform may comprise: decoding the demodulated and equalized data symbols to obtain data; or decoding the demodulated, inverse digital Fourier transformed and equalized data symbols to obtain data.

[0044] The configuration information may be received from a base station.

[0045] The configuration information may be received from the device.

[0046] The configuration information may comprise an explicit indication of the waveform of the response signal.

[0047] The configuration information may comprise an implicit indication of the waveform of the response signal.

[0048] The implicit indication of the waveform of the response signal may comprise a device type.

[0049] A device type may comprise a device type A, a device type B or a device type C.

[0050] The apparatus may be a reader.

[0051] The reader may be a user equipment.

[0052] The reader may be a base station.

[0053] The transformation may be a digital Fourier transformation.

[0054] The device may be an Internet of things device.

[0055] The device may be a passive device or an active device.

[0056] According to an aspect there is provided a computer program comprising computer executable code which when run on at least one processor is configured to: receive, from a device, a response signal to an activation signal over a channel; generate a first vector in a time domain including samples of the response signal; perform a transformation of the first vector in the time domain to obtain a second vector y_i in a frequency domain including pilot symbols and data symbols; estimate a channel response H_i of the channel based on the pilot symbols; equalize the data symbols based on the channel response H_i; determine a waveform of the response signal, from among a plurality of waveforms the apparatus is configurable to handle, based on configuration information; and process the equalized data symbols based on the determined waveform.

[0057] According to an aspect there is provided an apparatus comprising at least one processor and at least one memory storing instructions that, when executed by the at least one processor, cause the apparatus at least to: receive, from a base station, control information comprising an indication of a first frequency resource for transmitting, to a device, an activation signal and an indication of a second frequency resource for transmitting, to a reader, a response signal, wherein the first frequency resource is at least partially different from the second frequency resource; and transmit, to the device, the activation signal on the first frequency resource, wherein the activation signal comprises the indication of the second frequency resource for transmitting, to the reader, the response signal.

[0058] The activation signal may trigger the device to transmit the response signal.

[0059] The response signal may be dependent on the activation signal. The response signal may be a backscattered (i.e., reflected) modulation of the activation signal.

[0060] The device may be an active device. The response signal may be independent from the activation signal. The response signal may not be a backscattered (i.e., reflected) modulation of the activation signal.

[0061] The indication of the first frequency resource for transmitting, to the device, the activation signal may be an explicit indication; and the indication of the second frequency resource for transmitting, to the reader, the response signal may be an explicit indication.

[0062] The indication of the first frequency resource for transmitting, to the device, the activation signal may be an explicit indication; and the indication of the second frequency resource for transmitting, to the reader, the response signal may be an implicit indication.

[0063] The implicit indication may comprise a parameter to determine the second frequency resource based on the first frequency resource.

[0064] The first frequency resource may comprise at least one of a carrier or a subcarrier; and the second frequency resource may comprise at least one of a carrier or a subcarrier.

[0065] The control information may comprise an indication of a first time resource for transmitting, to the device, the activation signal and an indication of a second time resource for transmitting, to the reader, the response signal, wherein the first time resource is at least partly different from the second time resource.

[0066] The indication of the first time resource for transmitting, to the device, the activation signal may be an explicit indication; and the indication of the second time resource for transmitting, to the reader, the response signal may be an explicit indication.

[0067] The indication of the first time resource for transmitting, to the device, the activation signal may be an explicit indication; and the indication of the second time resource for transmitting, to the reader, the response signal may be an implicit indication.

[0068] The implicit indication may comprise a parameter to determine the second time resource based on the first time resource.

[0069] The first time resource may comprise at least one of a start time or a stop time; and the second time resource comprises at least one of a start time or a stop time.

[0070] The control information may be received on a downlink carrier.

[0071] The first frequency resource may comprise a downlink carrier and the second frequency resource a downlink carrier; the first frequency resource may comprise an uplink carrier and the second frequency resource comprises an uplink carrier;

[0072] the first frequency resource may comprise a downlink carrier and the second frequency resource comprises an uplink carrier; the first frequency resource may comprise an uplink carrier and the second frequency resource comprises a downlink carrier; the first frequency resource may comprise a carrier distinct from an uplink carrier and a downlink carrier and the second frequency resource comprises a downlink carrier; the first frequency resource may comprise a carrier distinct from an uplink carrier and a downlink carrier and the second frequency resource comprises an uplink carrier; or the first frequency resource may comprise a carrier distinct from an uplink carrier and a downlink carrier and the second frequency resource comprises a carrier distinct from an uplink carrier and a downlink carrier.

[0073] The base station may comprise a reader.

[0074] The first frequency resource may comprise a downlink carrier and the second frequency resource may comprise an uplink carrier; or the first frequency resource may comprise a carrier distinct from an uplink carrier and a downlink carrier and the second frequency resource may comprise an uplink carrier.

[0075] The apparatus may comprise an activator.

[0076] The apparatus may comprise a user equipment.

[0077] According to an aspect there is provided an apparatus comprising means for: receiving, from a base station, control information comprising an indication of a first frequency resource for transmitting, to a device, an activation signal and an indication of a second frequency resource for transmitting, to a reader, a response signal, wherein the first frequency resource is at least partially different from the second frequency resource; and transmitting, to the device, the activation signal on the first frequency resource, wherein the activation signal comprises the indication of the second frequency resource for transmitting, to the reader, the response signal.

[0078] According to an aspect there is provided an apparatus comprising circuitry configured to: receive, from a base station, control information comprising an indication of a first frequency resource for transmitting, to a device, an activation signal and an indication of a second frequency resource for transmitting, to a reader, a response signal, wherein the first frequency resource is at least partially different from the second frequency resource; and transmit, to the device, the activation signal on the first frequency resource, wherein the activation signal comprises the indication of the second frequency resource for transmitting, to the reader, the response signal.

[0079] According to an aspect there is provided a method comprising: receiving, from a base station, control information comprising an indication of a first frequency resource for transmitting, to a device, an activation signal and an indication of a second frequency resource for transmitting, to a reader, a response signal, wherein the first frequency resource is at least partially different from the second frequency resource; and transmitting, to the device, the activation signal on the first frequency resource, wherein the activation signal comprises the indication of the second frequency resource for transmitting, to the reader, the response signal.

[0080] The method may be performed by an apparatus.

[0081] The activation signal may trigger the device to transmit the response signal.

[0082] The response signal may be dependent on the activation signal. The response signal may be a backscattered (i.e., reflected) modulation of the activation signal.

[0083] The device may be an active device. The response signal may be independent from the activation signal. The response signal may not be a backscattered (i.e., reflected) modulation of the activation signal.

[0084] The indication of the first frequency resource for transmitting, to the device, the activation signal may be an explicit indication; and the indication of the second frequency resource for transmitting, to the reader, the response signal may be an explicit indication.

[0085] The indication of the first frequency resource for transmitting, to the device, the activation signal may be an explicit indication; and the indication of the second frequency resource for transmitting, to the reader, the response signal may be an implicit indication.

[0086] The implicit indication may comprise a parameter to determine the second frequency resource based on the first frequency resource.

[0087] The first frequency resource may comprise at least one of a carrier or a subcarrier; and the second frequency resource may comprise at least one of a carrier or a subcarrier.

[0088] The control information may comprise an indication of a first time resource for transmitting, to the device, the activation signal and an indication of a second time resource for transmitting, to the reader, the response signal, wherein the first time resource is at least partly different from the second time resource.

[0089] The indication of the first time resource for transmitting, to the device, the activation signal may be an explicit indication; and the indication of the second time resource for transmitting, to the reader, the response signal may be an explicit indication.

[0090] The indication of the first time resource for transmitting, to the device, the activation signal may be an explicit indication; and the indication of the second time resource for transmitting, to the reader, the response signal may be an implicit indication.

[0091] The implicit indication may comprise a parameter to determine the second time resource based on the first time resource.

[0092] The first time resource may comprise at least one of a start time or a stop time; and the second time resource comprises at least one of a start time or a stop time.

[0093] The control information may be received on a downlink carrier.

[0094] The first frequency resource may comprise a downlink carrier and the second frequency resource a downlink carrier; the first frequency resource may comprise an uplink carrier and the second frequency resource comprises an uplink carrier;

[0095] the first frequency resource may comprise a downlink carrier and the second frequency resource comprises an uplink carrier; the first frequency resource may comprise an uplink carrier and the second frequency resource comprises a downlink carrier; the first frequency resource may comprise a carrier distinct from an uplink carrier and a downlink carrier and the second frequency resource comprises a downlink carrier; the first frequency resource may comprise a carrier distinct from an uplink carrier and a downlink carrier and the second frequency resource comprises an uplink carrier; or the first frequency resource may comprise a carrier distinct from an uplink carrier and a downlink carrier and the second frequency resource comprises a carrier distinct from an uplink carrier and a downlink carrier.

[0096] The base station may comprise a reader.

[0097] The first frequency resource may comprise a downlink carrier and the second frequency resource may comprise an uplink carrier; or the first frequency resource may comprise a carrier distinct from an uplink carrier and a downlink carrier and the second frequency resource may comprise an uplink carrier.

[0098] The apparatus may comprise an activator.

[0099] The apparatus may comprise a user equipment.

[0100] According to an aspect there is provided a computer program comprising computer executable code which when run on at least one processor is configured to: receive, from a base station, control information comprising an indication of a first frequency resource for transmitting, to a device, an activation signal and an indication of a second frequency resource for transmitting, to a reader, a response signal, wherein the first frequency resource is at least partially different from the second frequency resource; and transmit, to the device, the activation signal on the first frequency resource, wherein the activation signal comprises the indication of the second frequency resource for transmitting, to the reader, the response signal.

[0101] According to an aspect there is provided an apparatus comprising at least one processor and at least one memory storing instructions that, when executed by the at least one processor, cause the apparatus at least to: determine a first frequency resource for transmitting, to a device, an activation signal and a second frequency resource for transmitting, to a reader, a response signal, wherein the first frequency resource is at least partially different from the second frequency resource.

[0102] The at least one memory may store instructions that, when executed by the at least one processor, cause the apparatus at least to: transmit, to an activator, control information comprising an indication of the first frequency resource for transmitting, to the device, the activation signal and an indication of the second frequency resource for transmitting, to the reader, the response signal.

[0103] The apparatus may comprise a base station.

[0104] The device may be an Internet of things device.

[0105] The device may be a passive device or an active device.

[0106] According to an aspect there is provided an apparatus comprising means for: determining a first frequency resource for transmitting, to a device, an activation signal and a second frequency resource for transmitting, to a reader, a response signal, wherein the first frequency resource is at least partially different from the second frequency resource.

[0107] According to an aspect there is provided an apparatus comprising circuitry configured to: determine a first frequency resource for transmitting, to a device, an activation signal and a second frequency resource for transmitting, to a reader, a response signal, wherein the first frequency resource is at least partially different from the second frequency resource.

[0108] According to an aspect there is provided a method comprising: determining a first frequency resource for transmitting, to a device, an activation signal and a second frequency resource for transmitting, to a reader, a response signal, wherein the first frequency resource is at least partially different from the second frequency resource.

[0109] The method may be performed by an apparatus.

[0110] The method may comprise: transmitting, to an activator, control information comprising an indication of the first frequency resource for transmitting, to the device, the activation signal and an indication of the second frequency resource for transmitting, to the reader, the response signal.

[0111] The apparatus may comprise a base station.

[0112] The device may be an Internet of things device.

[0113] The device may be a passive device or an active device.

[0114] According to an aspect there is provided a computer program comprising computer executable code which when run on at least one processor is configured to: determine a first frequency resource for transmitting, to a device, an activation signal and a second frequency resource for transmitting, to a reader, a response signal, wherein the first frequency resource is at least partially different from the second frequency resource.

[0115] According to an aspect there is provided an apparatus comprising at least one processor and at least one memory storing instructions that, when executed by the at least one processor, cause the apparatus at least to: receive, from a base station, downlink control information comprising: a frequency resource indication value including an indication of a first frequency resource for transmitting, to a device, an activation signal and an indication of a second frequency resource for transmitting, to a reader, a response signal, wherein the first frequency resource is at least partially different from the second frequency resource; and a time resource indication value including an indication of a first time resource for transmitting, to the device, the activation signal and an indication of a second time resource for transmitting, to the reader, the response signal, wherein the first time resource is at least partially different from the second time resource; and transmit, to the device, the activation signal on the first frequency resource, wherein the activation signal comprises the indication of the second frequency resource for transmitting, to the reader, the response signal.

[0116] The activation signal may trigger the device to transmit the response signal.

[0117] The response signal may be dependent on the activation signal. The response signal may be a backscattered (i.e., reflected) modulation of the activation signal.

[0118] The device may be an active device. The response signal may be independent from the activation signal. The response signal may not be a backscattered (i.e., reflected) modulation of the activation signal.

[0119] The indication of the first frequency resource for transmitting, to the device, the activation signal may be an explicit indication; and the indication of the second frequency resource for transmitting, to the reader, the response signal may be an explicit indication.

[0120] The indication of the first frequency resource for transmitting, to the device, the activation signal may be an explicit indication; and the indication of the second frequency resource for transmitting, to the reader, the response signal may be an implicit indication.

[0121] The implicit indication may comprise a parameter to determine the second frequency resource based on the first frequency resource.

[0122] The first frequency resource may comprise at least one of a carrier or a subcarrier; and the second frequency resource may comprise at least one of a carrier or a subcarrier.

[0123] The indication of the first time resource for transmitting, to the device, the activation signal may be an explicit indication; and the indication of the second time resource for transmitting, to the reader, the response signal may be an explicit indication.

[0124] The indication of the first time resource for transmitting, to the device, the activation signal may be an explicit indication; and the indication of the second time resource for transmitting, to the reader, the response signal may be an implicit indication.

[0125] The implicit indication may comprise a parameter to determine the second time resource based on the first time resource.

[0126] The first time resource may comprise at least one of a start time or a stop time; and the second time resource may comprise at least one of a start time or a stop time.

[0127] The downlink control information may be received on a downlink carrier.

[0128] The first frequency resource may comprise a downlink carrier and the second frequency resource a downlink carrier; the first frequency resource may comprise an uplink carrier and the second frequency resource comprises an uplink carrier;

[0129] the first frequency resource may comprise a downlink carrier and the second frequency resource comprises an uplink carrier; the first frequency resource may comprise an uplink carrier and the second frequency resource comprises a downlink carrier; the first frequency resource may comprise a carrier distinct from an uplink carrier and a downlink carrier and the second frequency resource comprises a downlink carrier; the first frequency resource may comprise a carrier distinct from an uplink carrier and a downlink carrier and the second frequency resource comprises an uplink carrier; or the first frequency resource may comprise a carrier distinct from an uplink carrier and a downlink carrier and the second frequency resource comprises a carrier distinct from an uplink carrier and a downlink carrier.

[0130] The base station may comprise a reader.

[0131] The first frequency resource may comprise a downlink carrier and the second frequency resource comprises an uplink carrier; or the first frequency resource may comprise a carrier distinct from an uplink carrier and a downlink carrier and the second frequency resource comprises an uplink carrier.

[0132] The apparatus may comprise an activator.

[0133] The apparatus may comprise a user equipment.

[0134] According to an aspect there is provided an apparatus comprising means for: receiving, from a base station, downlink control information comprising: a frequency resource indication value including an indication of a first frequency resource for transmitting, to a device, an activation signal and an indication of a second frequency resource for transmitting, to a reader, a response signal, wherein the first frequency resource is at least partially different from the second frequency resource; and a time resource indication value including an indication of a first time resource for transmitting, to the device, the activation signal and an indication of a second time resource for transmitting, to the reader, the response signal, wherein the first time resource is at least partially different from the second time resource; and transmitting, to the device, the activation signal on the first frequency resource, wherein the activation signal comprises the indication of the second frequency resource for transmitting, to the reader, the response signal.

[0135] According to an aspect there is provided an apparatus comprising circuitry configured to: receive, from a base station, downlink control information comprising: a frequency resource indication value including an indication of a first frequency resource for transmitting, to a device, an activation signal and an indication of a second frequency resource for transmitting, to a reader, a response signal, wherein the first frequency resource is at least partially different from the second frequency resource; and a time resource indication value including an indication of a first time resource for transmitting, to the device, the activation signal and an indication of a second time resource for transmitting, to the reader, the response signal, wherein the first time resource is at least partially different from the second time resource; and transmit, to the device, the activation signal on the first frequency resource, wherein the activation signal comprises the indication of the second frequency resource for transmitting, to the reader, the response signal.

[0136] According to an aspect there is provided a method comprising: receiving, from a base station, downlink control information comprising: a frequency resource indication value including an indication of a first frequency resource for transmitting, to a device, an activation signal and an indication of a second frequency resource for transmitting, to a reader, a response signal, wherein the first frequency resource is at least partially different from the second frequency resource; and a time resource indication value including an indication of a first time resource for transmitting, to the device, the activation signal and an indication of a second time resource for transmitting, to the reader, the response signal, wherein the first time resource is at least partially different from the second time resource; and transmitting, to the device, the activation signal on the first frequency resource, wherein the activation signal comprises the indication of the second frequency resource for transmitting, to the reader, the response signal.

[0137] The method may be performed by an apparatus.

[0138] The activation signal may trigger the device to transmit the response signal.

[0139] The response signal may be dependent on the activation signal. The response signal may be a backscattered (i.e., reflected) modulation of the activation signal.

[0140] The device may be an active device. The response signal may be independent from the activation signal. The response signal may not be a backscattered (i.e., reflected) modulation of the activation signal.

[0141] The indication of the first frequency resource for transmitting, to the device, the activation signal may be an explicit indication; and the indication of the second frequency resource for transmitting, to the reader, the response signal may be an explicit indication.

[0142] The indication of the first frequency resource for transmitting, to the device, the activation signal may be an explicit indication; and the indication of the second frequency resource for transmitting, to the reader, the response signal may be an implicit indication.

[0143] The implicit indication may comprise a parameter to determine the second frequency resource based on the first frequency resource.

[0144] The first frequency resource may comprise at least one of a carrier or a subcarrier; and the second frequency resource may comprise at least one of a carrier or a subcarrier.

[0145] The indication of the first time resource for transmitting, to the device, the activation signal may be an explicit indication; and the indication of the second time resource for transmitting, to the reader, the response signal may be an explicit indication.

[0146] The indication of the first time resource for transmitting, to the device, the activation signal may be an explicit indication; and the indication of the second time resource for transmitting, to the reader, the response signal may be an implicit indication.

[0147] The implicit indication may comprise a parameter to determine the second time resource based on the first time resource.

[0148] The first time resource may comprise at least one of a start time or a stop time; and the second time resource may comprise at least one of a start time or a stop time.

[0149] The downlink control information may be received on a downlink carrier.

[0150] The first frequency resource may comprise a downlink carrier and the second frequency resource a downlink carrier; the first frequency resource may comprise an uplink carrier and the second frequency resource comprises an uplink carrier;

[0151] the first frequency resource may comprise a downlink carrier and the second frequency resource comprises an uplink carrier; the first frequency resource may comprise an uplink carrier and the second frequency resource comprises a downlink carrier; the first frequency resource may comprise a carrier distinct from an uplink carrier and a downlink carrier and the second frequency resource comprises a downlink carrier; the first frequency resource may comprise a carrier distinct from an uplink carrier and a downlink carrier and the second frequency resource comprises an uplink carrier; or the first frequency resource may comprise a carrier distinct from an uplink carrier and a downlink carrier and the second frequency resource comprises a carrier distinct from an uplink carrier and a downlink carrier.

[0152] The base station may comprise a reader.

[0153] The first frequency resource may comprise a downlink carrier and the second frequency resource comprises an uplink carrier; or the first frequency resource may comprise a carrier distinct from an uplink carrier and a downlink carrier and the second frequency resource comprises an uplink carrier.

[0154] The apparatus may comprise an activator.

[0155] The apparatus may comprise a user equipment.

[0156] According to an aspect there is provided a computer program comprising computer executable code which when run on at least one processor is configured to: receive, from a base station, downlink control information comprising: a frequency resource indication value including an indication of a first frequency resource for transmitting, to a device, an activation signal and an indication of a second frequency resource for transmitting, to a reader, a response signal, wherein the first frequency resource is at least partially different from the second frequency resource; and a time resource indication value including an indication of a first time resource for transmitting, to the device, the activation signal and an indication of a second time resource for transmitting, to the reader, the response signal, wherein the first time resource is at least partially different from the second time resource; and transmit, to the device, the activation signal on the first frequency resource, wherein the activation signal comprises the indication of the second frequency resource for transmitting, to the reader, the response signal.

[0157] According to an aspect there is provided an apparatus comprising at least one processor and at least one memory storing instructions that, when executed by the at least one processor, cause the apparatus at least to: determine a first frequency resource for transmitting, to a device, an activation signal and a second frequency resource for transmitting, to a reader, a response signal, wherein the first frequency resource is different from the second frequency resource; and determine a first time resource for transmitting, to the device, the activation signal and a second time resource for transmitting, to the reader, the response signal, wherein the first time resource is at least partially different from the second time resource.

[0158] The at least one memory may store instructions that, when executed by the at least one processor, cause the apparatus at least to: transmit, to an activator, downlink control information comprising: a frequency resource indication value including an indication of the first frequency resource for transmitting, to the device, the activation signal and an indication of the second frequency resource for transmitting, to the reader, the response signal; and a time resource indication value including an indication of the first time resource for transmitting, to the device, the activation signal and an indication of the second time resource for transmitting, to the reader, the response signal.

[0159] The apparatus may comprise a base station.

[0160] The device may be an Internet of things device.

[0161] The device may be a passive device or an active device.

[0162] According to an aspect there is provided an apparatus comprising means for: determining a first frequency resource for transmitting, to a device, an activation signal and a second frequency resource for transmitting, to a reader, a response signal, wherein the first frequency resource is different from the second frequency resource; and determine a first time resource for transmitting, to the device, the activation signal and a second time resource for transmitting, to the reader, the response signal, wherein the first time resource is at least partially different from the second time resource.

[0163] According to an aspect there is provided an apparatus comprising circuitry configured to: determine a first frequency resource for transmitting, to a device, an activation signal and a second frequency resource for transmitting, to a reader, a response signal, wherein the first frequency resource is different from the second frequency resource; and determine a first time resource for transmitting, to the device, the activation signal and a second time resource for transmitting, to the reader, the response signal, wherein the first time resource is at least partially different from the second time resource.

[0164] According to an aspect there is provided a method comprising: determining a first frequency resource for transmitting, to a device, an activation signal and a second frequency resource for transmitting, to a reader, a response signal, wherein the first frequency resource is different from the second frequency resource; and determine a first time resource for transmitting, to the device, the activation signal and a second time resource for transmitting, to the reader, the response signal, wherein the first time resource is at least partially different from the second time resource.

[0165] The method may be performed by an apparatus.

[0166] The method may comprise: transmitting, to an activator, downlink control information comprising: a frequency resource indication value including an indication of the first frequency resource for transmitting, to the device, the activation signal and an indication of the second frequency resource for transmitting, to the reader, the response signal; and a time resource indication value including an indication of the first time resource for transmitting, to the device, the activation signal and an indication of the second time resource for transmitting, to the reader, the response signal.

[0167] The apparatus may comprise a base station.

[0168] The device may be an Internet of things device.

[0169] The device may be a passive device or an active device.

[0170] According to an aspect there is provided a computer program comprising computer executable code which when run on at least one processor is configured to: determine a first frequency resource for transmitting, to a device, an activation signal and a second frequency resource for transmitting, to a reader, a response signal, wherein the first frequency resource is different from the second frequency resource; and determine a first time resource for transmitting, to the device, the activation signal and a second time resource for transmitting, to the reader, the response signal, wherein the first time resource is at least partially different from the second time resource.

[0171] According to an aspect, there is provided a computer readable medium comprising program instructions stored thereon for performing at least one of the above methods.

[0172] According to an aspect, there is provided a non-transitory computer readable medium comprising program instructions stored thereon for performing at least one of the above methods.

[0173] According to an aspect, there is provided a non-volatile tangible memory medium comprising program instructions stored thereon for performing at least one of the above methods.

[0174] In the above, many different aspects have been described. It should be appreciated that further aspects may be provided by the combination of any two or more of the aspects described above.

[0175] Various other aspects are also described in the following detailed description and in the attached claims.

List of Abbreviations

[0176] AF: Application Function
[0177] AI: Artificial Intelligence
[0178] AIoT/A-IoT: Ambient Internet of Things
[0179] AMF: Access and Mobility Management Function
[0180] BS: Base Station
[0181] CU: Centralized Unit
[0182] DCI: Downlink Control Information
[0183] DL: Downlink
[0184] DU: Distributed Unit
[0185] FRIV: Frequency Resource Indicator Value
[0186] gNB: gNodeB
[0187] HSS: Home Subscriber Server
[0188] IoT: Internet of Things
[0189] LTE: Long Term Evolution
[0190] MAC: Medium Access Control
[0191] MS: Mobile Station
[0192] MTC: Machine Type Communication
[0193] NEF: Network Exposure Function

[0194] NF: Network Function

[0195] NR: New radio

[0196] NRF: Network Repository Function

[0197] RAM: Random Access Memory

[0198] (R)AN: (Radio) Access Network

[0199] ROM: Read Only Memory

[0200] SMF: Session Management Function

[0201] TRIV: Time Resource Indicator Value

[0202] UE: User Equipment

[0203] 5G: 5^{th} Generation

[0204] 5GC: 5G Core network

[0205] 5GS: 5G System

BRIEF DESCRIPTION OF THE FIGURES

[0206] Embodiments will now be described, by way of example only, with reference to the accompanying Figures in which:

[0207] FIG. **1** shows a schematic representation of a 5G system;

[0208] FIG. **2** shows a schematic representation of a control apparatus;

[0209] FIG. **3** shows a schematic representation of a user equipment;

[0210] FIG. **4** shows a schematic representation of three topologies (a), (b) and (c) for managing an ambient Internet of things device;

[0211] FIG. **5** shows a schematic representation of a topology (a) with three options for transmitting an activation signal and a response signal using frequency division duplex;

[0212] FIG. **6** shows a schematic representation of a topology (b) with two options for transmitting an activation signal and a response signal using frequency division duplex;

[0213] FIGS. **7**(*a*) and **7**(*b*) taken together show a schematic representation of a topology (c) with six options for transmitting an activation signal and a response signal using frequency division duplex;

[0214] FIG. **8** shows a block diagram of a method for receiving, from an ambient Internet of things device, a response signal;

[0215] FIG. **9** shows a block diagram of a method for transmitting, to an ambient Internet of things device, an activation signal;

[0216] FIG. **10** shows a block diagram of a method for transmitting, to an ambient Internet of things device an activation signal;

[0217] FIG. **11** shows a block diagram of a method for transmitting, to an ambient Internet of things device an activation signal;

[0218] FIG. **12** shows a block diagram of a method for transmitting, to an ambient Internet of things device an activation signal;

[0219] FIG. **13** shows a block diagram of a method for receiving, from an ambient Internet of things device, a response signal; and

[0220] FIG. **14** shows a schematic representation of a non-volatile memory medium storing instructions which when executed by a processor allow a processor to perform one or more of the steps of the methods of FIG. **9** to FIG. **13**.

DETAILED DESCRIPTION OF THE FIGURES

[0221] In the following certain embodiments are explained with reference to mobile communication devices capable of communication via a wireless cellular system and mobile communication systems serving such mobile communication devices. Before explaining in detail the exemplifying embodiments, certain general principles of a wireless communication system, access systems thereof, and mobile communication devices are briefly explained with reference to FIG. **1**, FIG. **2** and FIG. **3** to assist in understanding the technology underlying the described examples.

[0222] FIG. **1** shows a schematic representation of a 5G system (5GS). The 5GS may comprise Internet of things (IoT) devices, user equipment (UEs), a (radio) access network ((R)AN), a 5G core network (5GC), one or more application functions (AF) and one or more data networks (DN).

[0223] The IoT devices may comprise ambient IoT (AIoT) devices. An AIoT device may be configured to measure ambient conditions, such as location, temperature, pressure, noise, light or other ambient conditions. An AIoT device may comprise a sensor.

[0224] The UEs may comprise activator UEs, reader UEs or activator and reader UEs. An activator UE may be configured to transmit an activation signal to an AIoT device to trigger the AIoT device to transmit a response signal to a reader UE. A reader UE may be configured to receive a response signal from an AIoT device and to transmit a report signal to the 5G(R)AN.

[0225] The AIoT device may be of different types.

[0226] An AIoT device type A may refer to an AIoT device that does not have energy storage and that is not capable of transmitting a response signal to a reader UE independent from an activation signal received from an activator UE. The AIoT device may comprise a passive radio frequency transmission component. The AIoT device may be capable of transmitting a response signal dependent from an activation signal received from an activator UE. The response signal may be a backscattered (i.e., reflected) modulation of the activation signal received from an activator UE. The modulation may be used to convey content, such as an identifier of the AIoT device or a measurement performed by the AIoT device.

[0227] The power of the activation signal received from the activator UE may be controlled by the activator UE.

[0228] An AIoT device type B may refer to an AIoT device that has energy storage and that is not capable of transmitting a response signal to a reader UE independent from an activation signal received from an activator UE. The AIoT may comprise a passive radio frequency transmission component. The AIoT device may be capable of transmitting a response signal dependent on an activation signal received from an activator UE. The response signal may be a backscattered (i.e., reflected) modulation of the activation signal received from an activator UE, such as an identifier of the AIoT device or a measurement performed by the AIoT device. The power of the activation signal received from the activator UE may be controlled by the activator UE. The power of the response signal transmitted by the AIoT device may be controlled by the AIoT device. The power of the response signal transmitted by the AIoT device may not be controlled by the AIoT device.

[0229] An AIoT device type C may refer to an AIoT device that has energy storage and that is capable of transmitting a response signal independent from an activation signal received from an activator UE. The AIoT may comprise an active radio frequency transmission component. The power of the activation signal received from the activator UE may be controlled by the activator UE. The power of the response signal transmitted by the AIoT device may be controlled by the AIoT device.

[0230] For the case of AIoT device type A and AIoT device type B (i.e., the response signal may be a backscattered (i.e., reflected) modulation of the activation signal), there may be a relation between the activation signal and the response signal. For this reason, the control information may comprise the resource assignment for transmitting the activation signal and transmitting the response signal.

[0231] The 5G (R)AN may comprise one or more gNodeBs (gNBs). The gNodeBs may comprise one or more gNB distributed unit functions connected to one or more gNB centralized unit functions.

[0232] The gNodeBs may comprise activator gNodeBs, reader gNodeBs or activator and reader gNodeBs.

[0233] The 5GC may comprise an access and mobility management function (AMF), a session management function (SMF), an authentication server function (AUSF), a user data management (UDM), a user plane function (UPF), a network exposure function (NEF).

[0234] FIG. **2** illustrates an example of a control apparatus **200** for controlling a function of the (R)AN or the 5GC as illustrated on FIG. **1**. The control apparatus may comprise at least one random access memory (RAM) **211***a*, at least on read only memory (ROM) **211***b*, at least one processor **212**, **213** and an input/output interface **214**. The at least one processor **212**, **213** may be coupled to the RAM **211***a* and the ROM **211***b*. The at least one processor **212**, **213** may be configured to execute an appropriate software code **215**. The software code **215** may for example allow to perform one or more steps to perform one or more of the present aspects. The software code **215** may be stored in the ROM **211***b*. The control apparatus **200** may be interconnected with another control apparatus **200** controlling another function of the 5G (R)AN or the 5GC. In some embodiments, each function of the (R)AN or the 5GC comprises a control apparatus **200**. In alternative embodiments, two or more functions of the (R)AN or the 5GC may share a control apparatus.

[0235] FIG. **3** illustrates an example of a user equipment **300**, such as the terminal illustrated on FIG. **1**. The UE **300** may be provided by any device capable of sending and receiving radio signals. Non-limiting examples comprise a user equipment, a mobile station (MS) or mobile device such as a mobile phone or what is known as a 'smart phone', a computer provided with a wireless interface card or other wireless interface facility (e.g., USB dongle), a personal data assistant (PDA) or a tablet provided with wireless communication capabilities, a machine-type communications (MTC) device, a Cellular Internet of things (CIoT) device or any combinations of these or the like. The UE **300** may provide, for example, communication of data for carrying communications. The communications may be one or more of voice, electronic mail (email), text message, multimedia, data, machine data and so on.

[0236] The UE **300** may receive signals over an air or radio interface **307** via appropriate apparatus for receiving and may transmit signals via appropriate apparatus for transmitting radio signals. In FIG. **3** transceiver apparatus is designated schematically by block **306**. The transceiver apparatus **306** may be provided for example by means of a radio part and associated antenna arrangement. The antenna arrangement may be arranged internally or externally to the mobile device.

[0237] The UE **300** may be provided with at least one processor **301**, at least one memory ROM **302***a*, at least one RAM **302***b* and other possible components **303** for use in software and hardware aided execution of tasks it is designed to perform, including control of access to and communications with access systems and other communication devices. The at least one processor **301** is coupled to the RAM **302***b* and the ROM **302***a*. The at least one processor **301** may be configured to execute an appropriate software code **308**. The software code **308** may for example allow to perform one or more of the present aspects. The software code **308** may be stored in the ROM **302***a*.

[0238] The processor, storage and other relevant control apparatus can be provided on an appropriate circuit board and/or in chipsets. This feature is denoted by reference **304**. The device may optionally have a user interface such as keypad **305**, touch sensitive screen or pad, combinations thereof or the like. Optionally one or more of a display, a speaker and a microphone may be provided depending on the type of the device.

[0239] One or more aspect of this disclosure provides a mechanism for transmitting an activation signal and transmitting a response signal.

[0240] FIG. **4** shows a schematic representation of three topologies (a), (b) and (c) for managing an AIoT device.

[0241] The topology (a) comprises a gNB taking the role of a reader, an activator UE and an AIoT device.

[0242] The gNB may determine a resource assignment for transmitting an activation signal and a resource assignment for transmitting a response signal.

[0243] The gNB may transmit, to the activator, control information comprising an indication of the resource assignment for transmitting the activation signal and an indication of the resource assignment transmitting the response signal.

[0244] The activator UE may transmit, to the AIoT device, the activation signal based on the resource assignment for transmitting the activation signal. The activation signal may comprise the indication of the resource assignment for transmitting the response signal.

[0245] The AIoT device may transmit, to the gNB, the response signal based on the resource assignment for transmitting the response signal.

[0246] The gNB may decode the content of the response signal. The gNB may use the content of the response signal, for example to detect, read or localize the AIoT device.

[0247] The topology (b) comprises a gNB taking the role of an activator, UE an AIoT device and a reader UE.

[0248] The gNB may determine a resource assignment for transmitting an activation signal and a resource assignment for transmitting a response signal.

[0249] The gNB may transmit, to the AIoT device, the activation signal based on the resource assignment for transmitting the activation signal. The activation signal may comprise an indication of the resource assignment for transmitting the response signal.

[0250] The AIoT device may transmit, to the reader UE, the response signal based on the resource assignment for transmitting the response signal.

[0251] The reader UE may transmit, to the gNB a report signal based on the response signal. The gNB may receive the report signal. The gNB may decode the content of the report signal. The gNB may use the content of the report signal, for example to detect, read or localize the AIoT device.

[0252] The topology (c) comprises a gNB, an activator UE, an AIoT device and a reader UE.

[0253] The gNB may determine a resource assignment for transmitting an activation signal and a resource assignment for transmitting a response signal.

[0254] The gNB may transmit, to the activator UE, control information comprising an indication of the resource assignment for transmitting the activation signal and an indication of the resource assignment for transmitting a response signal.

[0255] The activator UE may transmit, to the AIoT device, the activation signal based on the resource assignment for transmitting the activation signal. The activation signal may comprise the indication of the resource assignment for transmitting the response signal.

[0256] The AIoT device may transmit, to the reader UE, the response signal based on the resource assignment for transmitting the response signal.

[0257] The reader UE may transmit, to the gNB a report signal based on the response signal.

[0258] The gNB may receive the report signal. The gNB may decode the content of the report signal. The gNB may use the content of the report signal, for example to detect, read or localize the AIoT device.

[0259] In the topology (a), the topology (b) or the topology (c), the control information may comprise downlink control information (DCI).

[0260] One or more aspect of this disclosure provides a mechanism for transmitting the activation signal and the response signal using frequency division duplex (FDD).

[0261] When the AIoT device may be an AIoT device type A or AIoT device type B AIoT device type, there may be a relation between the activation signal and the AIoT response (i.e., the response signal may be a backscattered (i.e., reflected) modulation of the activation signal received from an activator UE). This relation may refer to the fact that the response signal may only be transmitted while the activation signal is transmitted. This means the transmission of the activation signal and the transmission of the response signal may partially overlap.

[0262] The DCI may comprise a frequency resource indication value (FRIV) indicating a first frequency resource for transmitting the activation signal and a second frequency resource for transmitting the response signal. The first frequency resource may be at least partially different from the second frequency resource. The first frequency resource may comprise at least one of a carrier or a subcarrier. The second frequency resource may comprise at least one of a carrier or a subcarrier. The first frequency resource and the second frequency resource may be part of FR1.

[0263] The FRIV may explicitly indicate the first frequency resource and may explicitly indicate the second frequency resource.

[0264] Alternatively, the FRIV may explicitly indicate the first frequency resource and may implicitly indicate the second frequency resource. For example, the FRIV may indicate a parameter (e.g. frequency offset) to determine the second frequency resource based on the first frequency resource. The parameter may map the first frequency resource to the second frequency resource.

[0265] The DCI may comprise a time domain indication value (TRIV) comprising indicating a first time resource for transmitting the activation signal and a second time resource for transmitting the response signal. The first time resource may be at least partially different from the second time resource. The first time resource may comprise a start time and an end time. The second time resource may comprise a start time and an end time. The start time of the first time resource may be different from the start time of the second time resource. The end time of the first time resource may be the same as the end time of the second time resource.

[0266] The TRIV may explicitly indicate the first time resource and may explicitly indicate the second time resource.

[0267] Alternatively, the TRIV may explicitly indicate the first time resource and may implicitly indicate the second time resource. For example, the TRIV may indicate a parameter (e.g. time offset) to determine the second time resource based on the first time resource. The parameter may map the first time resource to the second time resource (e.g. the parameter may map the start time of the first time resource to the start time of the second time resource).

[0268] FIG. **5** shows a schematic representation of the topology (a) with three options for transmitting the activation signal and the response signal using FDD.

[0269] In option 1, the gNB may transmit the DCI on a downlink carrier. The activator UE may transmit the activation signal on an uplink carrier. The AIoT device may transmit the response signal on a downlink carrier.

[0270] In option 2, the gNB may transmit the DCI on a downlink carrier. The activator UE may transmit the activation signal on a downlink carrier. The AIoT device may transmit the response signal on an uplink carrier.

[0271] Alternatively, the AIoT device may transmit the response signal on a downlink carrier. This may be used when the AIoT device may not be able to switch to an uplink carrier to transmit the response signal. In this case the gNB may be able to operate capable in full Duplex operation or at least flexible duplex (e.g., half duplex or semi duplex).

[0272] In option 3, the gNB may transmit the DCI on a downlink carrier. The activator UE may transmit the activation signal on a carrier different from an uplink carrier and a downlink carrier. The AIoT device may transmit the response signal on an uplink carrier.

[0273] FIG. **6** shows a schematic representation of the topology (b) with two options for transmitting the activation signal and the response signal using FDD.

[0274] In option 1, the gNB (i.e., activator) may transmit the activation signal on a downlink carrier. Alternatively, the gNB (i.e., activator) may transmit the activation signal on an uplink carrier. The AIoT device may transmit the response signal on a downlink carrier. The reader UE may transmit the report signal on an uplink carrier. That is, the gNB may apply full duplex transmission and reception on an uplink carrier.

[0275] In option 2, the gNB (i.e., activator) may transmit the activation signal on a downlink carrier. Alternatively, the gNB (i.e., activator) may transmit the activation signal on an uplink carrier. The AIoT device may transmit the response signal on a carrier different from an uplink carrier and a downlink carrier. The reader UE may transmit the report signal on an uplink carrier. That is, the gNB may apply full duplex transmission and reception on an uplink carrier.

[0276] FIGS. 7(a) and 7(b) taken together show a schematic representation of the topology (c) with six options for transmitting the activation signal and the response signal using FDD.

[0277] In option 1, the gNB may transmit the DCI on a downlink carrier. The activator UE may transmit the activation signal on a downlink carrier. The AIoT device may transmit the response signal on a downlink carrier. The reader UE may transmit the report signal on an uplink carrier.

[0278] In option 2, the gNB may transmit the DCI on a downlink carrier. The activator UE may transmit the activation signal on an uplink carrier. The AIoT device may transmit the response signal on an uplink carrier. The reader UE may transmit the report signal on an uplink carrier.

[0279] In option 3, the gNB may transmit the DCI on a downlink carrier. The activator UE may transmit the activation signal on a downlink carrier. The AIoT device may transmit the response signal on an uplink carrier. The reader UE may transmit the report signal on an uplink carrier.

[0280] In option 4, the gNB may transmit the DCI on a downlink carrier. The activator UE may transmit the activation signal on an uplink carrier. The AIoT device may transmit the response signal on a downlink carrier. The reader UE may transmit the report signal on an uplink carrier.

[0281] In option 5, the gNB may transmit the DCI on a downlink carrier. The activator UE may transmit the activation signal on a carrier different from an uplink carrier and a downlink carrier. The AIoT device may transmit the response signal on a downlink carrier. The reader UE may transmit the report signal on an uplink carrier.

[0282] In option 6, the gNB may transmit the DCI on a downlink carrier. The activator UE may transmit the activation signal on a carrier different from an uplink carrier and a downlink carrier. The AIoT device may transmit the response signal on an uplink carrier. The reader UE may transmit the report signal on an uplink carrier.

[0283] In option 7, the gNB may transmit the DCI on a downlink carrier. The activator UE may transmit the activation signal on a carrier different from an uplink carrier and a downlink carrier. The AIoT device may transmit the response signal on a carrier different from an uplink carrier and a downlink carrier. The reader UE may transmit the report signal on an uplink carrier.

[0284] One or more aspect of this disclosure provides a mechanism for receiving a response signal.

[0285] The AIoT device may transmit the response signal using a waveform. The waveform may comprise orthogonal frequency division duplex multiplexing (OFDM) or digital Fourier Transform spread frequency division multiplexing (DFT-s-FDM). An example of OFDM is cyclic prefix OFDM (CP-OFDM).

[0286] The decision to transmit the response signal using the waveform may be made by the gNB. A reader UE may comprise an OFDM receiver and a DFT-s-FDM receiver to decode OFDM and DFT-s-FDM. By default the reader UE may use the OFDM receiver. The reader UE may switch between the OFDM receiver and the DFT-s-FDM receiver when appropriate to receive the response signal.

CP-OFDM

[0287] When the response signal is transmitted using CP-OFDM, the response signal may comprise B symbols per frame. During a i-th transmission, $i \in [B-1]$, a vector $u_i \in \{0, 1\}^K$ of bits may be encoded by the AIoT device with a code rate R and interleaved into the vector:

$$c_i = \left[\left(c_i^{(0)}\right)^T, \ldots, \left(c_i^{N_D-1}\right)^T\right]^T \tag{1}$$

with entries $c_i^{(k)} \in \{0,1\}^Q$, $k \in [N_D-1]$, $R*N_D*Q=K$, Q the length of the vector. By [P] we denote the set $\{p \in \mathbb{N} \mid 0 \le p \le P\}$. The vector c_i is modulated onto a vector of N_D complex symbols that are interleaved with N_P pilots to yield the symbol $x_i \in \mathbb{C}^N$, $N_P+N_D=M$.

[0288] Note that if the response signal does not contain any encoded data (e.g., payload), then all symbols may be considered as pilots and the encoding operation above may be skipped. In this case, $N_P=M$ and $N_D=0$.

[0289] The m-th entry $x_i[m]$ of x_i is a pilot symbol if $m \in P$ and a data symbol if $m \in D$. Here, $P=\{p_0, \ldots, p_{N_P-1}\}$ and $D=\{d_0, \ldots, d_{N_D-1}\}$, $P \cup D=[M-1]$, $P \cap D=\emptyset$, are the subsets of pilot and data indexes, respectively. Note that:

$$x_i[d_k]=\mathcal{M}(c_i^{(k)}) \tag{2},$$

where $\mathcal{M}: \{1,0\}^Q \rightarrow S_d$ denotes the complex modulation mapping, and S_d is the complex symbol constellation with cardinality 2^Q.

[0290] The vector x_i may be passed through an inverse discrete Fourier transform block and the resulting vector s_i is prepended a μ-sample long cyclic prefix.

[0291] Each symbol s_i in the B-long symbols frame may be sent then by the AIoT device over a channel (e.g. uplink channel) with response composed of L multipath components:

$$g_i(\tau) = \sum_{l=0}^{L-1} h_i(l)\delta(\tau - \tau_i(l)) \tag{3}$$

where $h_i(l)$ and $\tau_i(l)$ model the gain and delay of the l-th multipath component.

[0292] The reader UE may observe a response signal which is sampled at a rate $1/T_s$, and the CP samples are discarded. The remaining samples are collected in B vectors that are passed through an M-point DFT block, at the output of which the received vector is:

$$y_i = H_i x_i + w_i \tag{4}$$

where $i \in [B-1]$ and the matrix $H_i \in \mathbb{C}^{M \times M}$ is diagonal, with diagonal entries:

$$H_i[m, m] = \frac{1}{M}\sum_{l=0}^{L-1} h_i(l)\exp\left(\frac{j2\pi p\tau_i(l)}{MT_s}\right)$$

with. The vector w_i is additive white gaussian noise with zero mean and variance $\sigma^2 I_N$.

DFT-s-OFDM

[0293] The operations (1) and (2) explained above may be implemented to yield N_D sub-symbols $x_i[v]=\mathcal{M}(c_i^{(v)})$,

$v \in [N_D-1]$. Note that if the response signal does not contain any encoded data (e.g., payload), then all symbols may be considered as pilots and the encoding operation above is skipped. In this case, $N_P=M$ and $N_D=0$.

[0294] These may be passed through a DFT block, the output of which reads

$$\tilde{x}_i(d_k) = \frac{1}{\sqrt{N_D}} \sum_{v=0}^{N_D-1} x_i[v] \exp\left(\frac{-j2\pi kv}{N_D}\right)$$

which in matrix notation is:

$$\tilde{x}_i = Dx_i \tag{5}$$

where $d_k \in D$, and $D=\{d_0, \ldots, d_{N_D-1}\}$ may denote the same data subcarriers set and the matrix D may have the entry

$$D(k, v) = \frac{1}{\sqrt{N_D}} \exp\left(\frac{-j2\pi kv}{N_D}\right), k = 1:N_D, v = 1:N_D.$$

[0295] Then, the vector $\tilde{x}_i$ may be interleaved with the pilot vector. The resulting vector m-th entry $\tilde{x}_i[m]$ is a pilot symbol if $m \in P$ and a data symbol if $m \in D$. Here, $P=\{p_0, \ldots, p_{N_P-1}\}$ and $D=\{d_0, \ldots, d_{N_D-1}\}$, $P \cup D=[M-1]$, $P \cap D=\emptyset$, may be the subsets of pilot and data indexes, respectively, the same as in the CP-OFDM.

[0296] Finally, the resulting vector is converted to time-domain via inverse DFT of size M, the same as in CP-OFDM. The resulting vector s_i may be prepended a μ-sample long cyclic prefix (CP).

[0297] Each symbol s_i in the B-long symbols frame may sent then by the AIoT device over a channel (e.g. UL channel) with response composed of L multipath components $g_i(\tau)=\Sigma_{i=0}^{L-1} h_i(l)\delta(\tau-\tau_i(l))$, here $h_i(l)$ and $\tau_i(l)$ model the gain and delay of the l-th multipath component.

[0298] The reader UE may observe a response signal which is sampled at a rate $1/T_s$, and the CP samples are discarded.

[0299] The remaining samples may be collected in B vectors that are passed through an M-point DFT block, at the output of which the received vector is:

$$y_i = H_i \tilde{x}_i + w_i \tag{6}$$

where $i \in [B-1]$ and the matrix $H_i \in \mathbb{N}^{M \times M}$ is diagonal, with diagonal entries:

$$H_i[m, m] = \frac{1}{M} \sum_{l=0}^{L-1} h_i(l) \exp\left(\frac{j2\pi p \tau_i(l)}{MT_s}\right).$$

The vector w_i is additive white gaussian noise with zero mean and variance $\sigma^2 I_N$.

[0300] FIG. **8** shows a block diagram of a method for receiving, from an AIoT device, a response signal.

[0301] A reader UE may receive, from an AIoT device, a response signal over a channel. The reader UE may collect samples of the response signal. The samples of the response signal may comprise cyclic prefix samples and remaining samples. The reader UE may generate a first vector comprising the remaining samples. The reader UE may perform a digital Fourier transformation of the first vector to obtain a second vector y_i. The second vector y_i may comprise data symbols and pilot symbols. The data symbols may be mapped to data subcarriers. The pilot symbols may be mapped to pilot subcarriers.

[0302] The reader UE may determine a waveform of the response signal. The reader UE may determine the waveform of the response signal based on information, for example configuration information, received from the gNB or from the AIoT device. The information may comprise an explicit indication of the waveform of the response signal. Alternatively, the information may comprise an implicit indication of the waveform of the response signal.

[0303] An implicit indication of the waveform of the response signal may comprise an AIoT device type. The reader UE may determine a waveform of the response signal based on a waveform of the activation signal and the AIoT device type. For example, an AIoT device type A or AIoT device type B device may use the same waveform for the activation signal and the response signal or a different waveform for the activation signal and the response signal.

[0304] The reader UE may estimate a channel response H_i of the channel based on the pilot symbols.

[0305] The reader UE may equalize the data symbols based on the channel response H_i (e.g., least square or minimum mean square error equalization).

[0306] The reader UE may determine that the waveform of the response signal is OFDM (e.g., CP-OFDM). The reader UE may demodulate the equalized data symbols to obtain demodulated and equalized data symbols. The reader UE may or may not decode the demodulated and equalized data symbols to obtain data. The reader UE may transmit a report signal comprising the decoded or not decoded, demodulated, inverse digital Fourier transformed and equalized data symbols.

[0307] Alternatively, the reader UE may determine that the waveform of the response signal is DFT-s-FDM. The reader UE may perform inverse digital Fourier transformation of the equalized data symbols (e.g., of size N_D) to obtain inverse digital Fourier transformed and equalized data symbols. The reader UE may demodulate the inverse digital Fourier transformed and equalized data symbols to obtain demodulated, inverse digital Fourier transformed and equalized data symbols. The reader UE may or may not decode the demodulated, inverse digital Fourier transformed and equalized data symbols to obtain data. The reader UE may transmit a report signal comprising the decoded or not decoded, demodulated, inverse digital Fourier transformed and equalized data symbols.

[0308] FIG. **9** shows a block diagram of a method for transmitting, to an AIoT device, an activation signal.

[0309] At step **900**, an apparatus may receive, from a base station, control information comprising an indication of a first frequency resource for transmitting, to a device, an activation signal and an indication of a second frequency resource for transmitting, to a reader, a response signal, wherein the first frequency resource is at least partially different from the second frequency resource.

[0310] At step **902**, the apparatus may transmit, to the device, the activation signal on the first frequency resource, wherein the activation signal comprises the indication of the second frequency resource for transmitting, to the reader, the response signal.

[0311] FIG. **10** shows a block diagram of a method for transmitting, to an AIoT device, an activation signal.

[0312] At step **1000**, an apparatus may determine a first frequency resource for transmitting, to a device, an activation signal and a second frequency resource for transmitting, to a reader, a response signal, wherein the first frequency resource is at least partially different from the second frequency resource.

[0313] FIG. **11** shows a block diagram of a method for transmitting, to an AIoT device, an activation signal.

[0314] At step **1100**, an apparatus may receive, from a base station, downlink control information comprising: a FRIV including an indication of a first frequency resource for transmitting, to a device, an activation signal and an indication of a second frequency resource for transmitting, to a reader, a response signal, wherein the first frequency resource is at least partially different from the second frequency resource; and a TRIV including an indication of a first time resource for transmitting, to the device, the activation signal and an indication of a second time resource for transmitting, to the reader, the response signal, wherein the first time resource is at least partially different from the second time resource.

[0315] At step **1102**, the apparatus may transmit, to the device, the activation signal on the first frequency resource, wherein the activation signal comprises the indication of the second frequency resource for transmitting, to the reader, the response signal.

[0316] FIG. **12** shows a block diagram of a method for transmitting, to an AIoT device, an activation signal.

[0317] At step **1200**, the apparatus may determine a first frequency resource for transmitting, to a device, an activation signal and a second frequency resource for transmitting, to a reader, a response signal, wherein the first frequency resource is different from the second frequency resource.

[0318] At step **1202**, the apparatus may determine a first time resource for transmitting, to the device, the activation signal and a second time resource for transmitting, to the reader, the response signal, wherein the first time resource is at least partially different from the second time resource.

[0319] FIG. **13** shows a block diagram of a method for receiving, from an AIoT device, a response signal.

[0320] At step **1300**, an apparatus may receive, from a device, a response signal to an activation signal over a channel.

[0321] At step **1302**, the apparatus may generate a first vector in a time domain including samples of the response signal.

[0322] At step **1304**, the apparatus may perform a transformation of the first vector in the time domain to obtain a second vector y_i in a frequency domain including pilot symbols and data symbols.

[0323] At step **1306**, the apparatus may estimate a channel response H_i of the channel based on the pilot symbols.

[0324] At step **1308**, the apparatus may equalize the data symbols based on the channel response H_i.

[0325] At step **1310**, the apparatus may determine a waveform of the response signal from among a plurality of waveforms the apparatus is configurable to handle based on configuration information.

[0326] At step **1312**, the apparatus may process the equalized data symbols based on the waveform.

[0327] FIG. **14** shows a schematic representation of non-volatile memory media **1400** storing instructions which when executed by a processor allow the processor to perform one or more of the steps of the methods of FIG. **9** to FIG. **13**.

[0328] It is noted that while the above describes example embodiments, there are several variations and modifications which may be made to the disclosed solution without departing from the scope of the present invention.

[0329] It will be understood that although the above concepts have been discussed in the context of a 5GS, one or more of these concepts may be applied to other cellular systems.

[0330] The embodiments may thus vary within the scope of the attached claims. In general, some embodiments may be implemented in hardware or special purpose circuits, software, logic or any combination thereof. For example, some aspects may be implemented in hardware, while other aspects may be implemented in firmware or software which may be executed by a controller, microprocessor or other computing device, although embodiments are not limited thereto. While various embodiments may be illustrated and described as block diagrams, flow charts, or using some other pictorial representation, it is well understood that these blocks, apparatus, systems, techniques or methods described herein may be implemented in, as non-limiting examples, hardware, software, firmware, special purpose circuits or logic, general purpose hardware or controller or other computing devices, or some combination thereof.

[0331] The embodiments may be implemented by computer software stored in a memory and executable by at least one data processor of the involved entities or by hardware, or by a combination of software and hardware. Further in this regard it should be noted that any procedures, e.g., as in FIG. **9** to FIG. **13**, may represent program steps, or interconnected logic circuits, blocks and functions, or a combination of program steps and logic circuits, blocks and functions. The software may be stored on such physical media as memory chips, or memory blocks implemented within the processor, magnetic media such as hard disk or floppy disks, and optical media such as for example DVD and the data variants thereof, CD.

[0332] The memory may be of any type suitable to the local technical environment and may be implemented using any suitable data storage technology, such as semiconductor-based memory devices, magnetic memory devices and systems, optical memory devices and systems, fixed memory and removable memory. The data processors may be of any type suitable to the local technical environment, and may include one or more of general purpose computers, special purpose computers, microprocessors, digital signal processors (DSPs), application specific integrated circuits (ASIC), gate level circuits and processors based on multi-core processor architecture, as non-limiting examples.

[0333] Alternatively or additionally some embodiments may be implemented using circuitry. The circuitry may be configured to perform one or more of the functions and/or method steps previously described. That circuitry may be provided in the base station and/or in the communications device.

[0334] As used in this application, the term "circuitry" may refer to one or more or all of the following:

[0335] (a) hardware-only circuit implementations (such as implementations in only analogue and/or digital circuitry);

[0336] (b) combinations of hardware circuits and software, such as:

[0337] (i) a combination of analogue and/or digital hardware circuit(s) with software/firmware and

[0338] (ii) any portions of hardware processor(s) with software (including digital signal processor(s)), software, and memory(ies) that work together to cause an apparatus, such as the communications device or base station to perform the various functions previously described; and

[0339] (c) hardware circuit(s) and or processor(s), such as a microprocessor(s) or a portion of a microprocessor (s), that requires software (e.g., firmware) for operation, but the software may not be present when it is not needed for operation.

[0340] This definition of circuitry applies to all uses of this term in this application, including in any claims. As a further example, as used in this application, the term circuitry also covers an implementation of merely a hardware circuit or processor (or multiple processors) or portion of a hardware circuit or processor and its (or their) accompanying software and/or firmware. The term circuitry also covers, for example integrated device.

[0341] The foregoing description has provided by way of exemplary and non-limiting examples a full and informative description of some embodiments However, various modifications and adaptations may become apparent to those skilled in the relevant arts in view of the foregoing description, when read in conjunction with the accompanying drawings and the appended claims. However, all such and similar modifications of the teachings will still fall within the scope as defined in the appended claims.

1. An apparatus comprising at least one processor and at least one memory storing instructions that, when executed by the at least one processor, cause the apparatus at least to:

receive, from a device, a response signal to an activation signal over a channel;

generate a first vector in a time domain including samples of the response signal;

perform a transformation of the first vector in the time domain to obtain a second vector y_i in a frequency domain including pilot symbols and data symbols;

estimate a channel response H_i of the channel based on the pilot symbols;

equalize the data symbols based on the channel response H_i;

determine a waveform of the response signal, from among a plurality of waveforms the apparatus is configurable to handle, based on configuration information; and

process the equalized data symbols based on the determined waveform.

2. The apparatus of claim **1**, wherein the at least one memory stores instructions that, when executed by the at least one processor, cause the apparatus at least to:

sample the response signal to generate cyclic prefix samples and remaining sample; and

delete the cyclic prefix samples; and

wherein the first vector include the remaining samples.

3. The apparatus of claim **1**, wherein determining a waveform of the response signal comprises:

determining that a waveform of the response signal comprise a first waveform; and

wherein processing the data symbols based on the determined waveform comprises:

demodulating the equalized data symbols to obtain demodulated and equalized data symbols.

4. The apparatus of claim **3**, wherein the first waveform comprises orthogonal frequency division multiplexing.

5. The apparatus of claim **4**, wherein the first waveform comprises cyclic prefix orthogonal frequency division multiplexing.

6. The apparatus of claim **1**, wherein determining a waveform of the response signal comprises:

determining that a waveform of the response signal is a second waveform; and

wherein processing the data symbols based on the determined waveform comprises:

performing an inverse digital Fourier transformation of the equalized data symbols to obtain inverse digital Fourier transformed and equalized data symbols; and

demodulating the inverse digital Fourier transformed and equalized data symbols to obtain demodulated, inverse digital Fourier transformed and equalized data symbols.

7. The apparatus of claim **6**, wherein the second waveform comprises digital Fourier transform spread frequency division multiplexing.

8. The apparatus of claim **3**, wherein processing the data symbols based on the determined waveform comprises:

decoding the demodulated and equalized data symbols to obtain data; or

decoding the demodulated, inverse digital Fourier transformed and equalized data symbols to obtain data.

9. The apparatus of claim **1**, wherein the configuration information is received from a base station.

10. The apparatus of claim **1**, wherein the configuration information is received from the device.

11. The apparatus of claim **9**, wherein the configuration information comprises an explicit indication of the waveform of the response signal.

12. The apparatus of claim **9**, wherein the configuration information comprises an implicit indication of the waveform of the response signal.

13. The apparatus of claim **12**, wherein the implicit indication of the waveform of the response signal comprises a device type.

14. The apparatus of claim **1**, wherein the apparatus is a reader.

15. The apparatus of claim **14**, wherein the reader is a user equipment.

16. The apparatus of claim **14**, wherein the reader is a base station.

17. The apparatus of claim **1**, wherein the transformation is a digital Fourier transformation.

18. The apparatus of claim **1**, wherein the device is an Internet of things device.

19. (canceled)

20. A method comprising:

receiving, from a device, a response signal to an activation signal over a channel;

generating a first vector in a time domain including samples of the response signal;

performing a transformation of the first vector in the time domain to obtain a second vector y_i in a frequency domain including pilot symbols and data symbols;

estimating a channel response H_i of the channel based on the pilot symbols;

equalizing the data symbols based on the channel response H_i;

determining a waveform of the response signal, from among a plurality of waveforms, the apparatus is configurable to handle based on configuration information; and

processing the equalized data symbols based on the determined waveform.

21. A non-transitory computer readable medium comprising program instructions which when run on one or more processors perform the method of claim **20**.

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