

The invention relates to a radar unit according to the concept of patent claim 1.

A radar unit of this type with synthetic aperture on the basis of rotating antennae (ROSAR) is known from the publication ntz-Archiv, Vol. 9, 1987, No. 1, p. 13 - 23. There, the antennae are arranged at the ends of a rotating support arm, for example at the blade tips of helicopter rotors. The radar process with synthetic aperture is based on the evaluation of Doppler information for each individual point on the ground within the real antenna lobe, thus necessitating a relative movement of the antenna and a pulsed coherent radar unit. The relative movement of the antenna of a ROSAR apparatus is generated by a rotational movement of the antennae relative to the target to be detected. The receive signal is cross-correlated pulse by pulse by means of a set of reference functions derived from the illumination geometry with the availability of a reference function for each range element or each resolution cell on the ground. This computer-intensive processing offers an adapted filter resulting in increased cross-resolution relative to the real antenna lobe. This allows an increase by one order of magnitude with synthetic aperture as compared to the resolution with real aperture.

If the antennae are arranged on the blade tips of a helicopter rotor, then the rotational speed of approximately 200 m/sec at the blade tips is significantly higher than the cruising speed of the helicopter above ground. The Doppler information, which is produced on the basis of the rotational speed of the blade tips, is then considerably higher than the one produced on the basis of a translatory movement of the helicopter, so that the latter

Doppler displacement is not normally to be taken into consideration. The antennae fitted in the rotor-blade tips illuminate, by virtue of their angular downward line of sight, a circular area, its illuminated strip width being dependent on the aperture angle in elevation, the depression angle, i.e. the angle between the line of sight of the antenna and the horizontal, and the height of the antenna above ground. Echoes originating from the illuminated strip are, due to their Doppler modulation, compressed to increased azimuth resolution, and for each range point on the ground is known the Doppler time function as an associated reference function. This reference function can be deterministically calculated for each point on the ground. The entire radar system thus represents an adapted filter, and focused processing is a precondition.

If an acceptable resolution within a range of one metre is to be obtained by means of such a ROSAR apparatus, then a plurality of correlation calculations have to be carried out within a short period of time, i.e. an enormous flow of data has to be processed. A processor capable of processing such a flow of data would have to comprise a special processor structure adapted to the ROSAR-principle, but this could not be offered in the aforementioned article.

From the DE-A 28 35 932 is known a ROSAR apparatus with the antennae arranged in the blade tips of a helicopter rotor. This apparatus is to be used as a cartography radar apparatus. However, this concept accepts a few restrictions in order to simplify the processor structure and to permit conventional signal processing: Essentially, only stationery targets are to be detected, but not moving targets.

The correlation calculations can then be combined over several periods of rotor rotation, however, this ROSAR apparatus can then not be described as a real-time radar apparatus and is consequently not suitable, for example, for navigation or target tracking. Furthermore, this known concept neglects the altitude of the helicopter above ground, as this is always seen to be very large relative to the dimensions of a target. Furthermore, no consideration is given to the distortion of illuminated areas by the rotating antennae, i.e. the curvature of the individual resolution cells. The curvature is described as range curvature.

From the US-A 4 638 315 is known a radar unit with synthetic aperture, with the radar transmitter fixed, for example in the helicopter cockpit, whilst the receive antenna rotates and is fitted, for example, on the rotor-blade tip. The radar transmitter illuminates the area to be monitored whilst the reflected signals are picked up by the rotating antenna. A thus produced Doppler displacement is compensated by generating a pilot signal. A range signal can then be obtained by frequency mixing. Actually, this radar unit is not a ROSAR apparatus as the forming of reference functions and a cross-correlation are dispensed with.

It is an object of the invention to offer a new processor structure, in particular for forming reference functions, by means of which the resolution of the ROSAR apparatus is increased and distortions of calculated data are largely prevented.

This object is achieved according to the invention by the features contained in the characterizing portion of Patent Claim 1.

Accordingly, a geometric module calculates from the opening- and depression angle of the antenna, the length of the rotating arm and the height of the antenna above ground the width of a range strip illuminated by the antenna and the range difference between the beams from the antenna to the front or the rear of the illuminated strip edge. In a circuit, this illuminated strip is resolved into a specified number of range intervals or range cells. The reference functions are then calculated for these individual range cells. The actual result signal, which is conventionally stored and, if appropriate, displayed, is then obtained by a controlled cross-correlation of the incoming signals with the reference functions of the associated range cells.

The circuit for dividing the illuminated strip into a specified number of range cells then preferably comprises a module for calculating the number of these range cells within the illuminated strip, and this calculation is carried out by way of a calculated range difference and the antenna characteristics and the desired radial resolution. The individual range intervals can then be calculated from this number within the illuminated strip. Furthermore, a module is provided for calculating the integration time for the individual range intervals, and so is a module for calculating the number of transmit pulses and the rotary angle range for the range intervals based on the integration time. A circuit of this type ensures that only signals of previously determined range intervals are cross-correlated with each other.

By splitting the processor structure into individual modules which are laid out for specific

tasks, it is possible, in spite of a high flow of data, to process incoming signals in such a manner that a high resolution is achieved with a reasonable effort. Only here does it become possible to generate an image.

If the antennae are fitted to the blade tips of a helicopter rotor, then it is possible with the aid of a kinematic sensor, for example with the aid of acceleration pickups, to determine the altitude flap of the helicopter rotor and also the deviation from a constant angular speed and to use these measuring values for correcting the evaluation. Corrections of respectively calculated reference functions, necessary due to the altitude flap and the varying angular speed, are made possible by adding a number of correcting terms.

A ROSAR apparatus according to the invention can be used, for example, for air reconnaissance, navigation, for example for navigation of rescue helicopters, cartography, measuring dimensions of ocean waves, searching for open and concealed land mines, etc. The radar unit can be stationary or fitted to vehicles. The described arrangement of the processor structure makes it possible in particular to effectively and quasi in real time process radar signals from close range, which is indispensable for navigational processes.

Further arrangements of the invention are contained in the subclaims.

The invention will now be described by way of an exemplary embodiment and based on the drawing. Shown are, in

Fig. 1a

and 1b: the illumination geometry, not to scale, of a ROSAR apparatus the antennae of which are fitted to the rotor-blade tips of a helicopter;

Fig. 2a

and 2b: a section of the illumination geometry for the purpose of describing controlling parameters;

Fig. 3: a section of the illumination geometry for the purpose of describing the positioning of the range intervals within an illuminated strip;

Fig. 4: a block-circuit diagram of a ROSAR processor according to the invention, which is provided with a geometric module for forming the reference functions, a module for calculating the number of range intervals within an illuminated strip, a module for calculating the range intervals, a module for determining the integration time for the individual range intervals, and a module for calculating support points for the reference function, as well as modules for generating and storing the reference functions for individual range intervals.

Fig. 5: a diagrammatic illustration of a geometric module;

Fig. 6: a diagrammatic illustration of a module for calculating the number of range intervals;

Fig. 7: a diagram of a module for calculating the individual range intervals;

- Fig. 8: a diagrammatic illustration of a module for calculating the integration time;
- Fig. 9: a diagrammatic illustration of a module for determining the support points for calculating the reference functions;
- Fig. 10: a diagrammatic illustration of a module for calculating the reference functions;
- Fig. 11a
and 11b: one each layout illustration of a store for the reference functions or the scanned receive signals;
- Fig. 12: a layout illustration of the correlator;
- Fig. 13: a diagrammatic illustration of a module for the reference function under different proximity conditions;
- Fig. 14: a diagrammatic view of the blade tip of a helicopter rotor with an antenna and a kinematic sensor for taking into account the elevator move of the rotor and the non-constant rotor frequency;
- Fig. 15: a diagrammatic illustration of a helicopter with a modified ROSAR unit according to the invention;
- Fig. 16: A block circuit diagram for wireless transfer of energy between a helicopter and the rotors.

The formulae shown in the figures are a direct part of this specification, even without explicit reference to a respective figure being made. This allows easy reading.

A helicopter 1 comprises a four-blade rotor 2 having a respective antenna 3 fitted to its blade tips at a distance L from the rotor axis. The rotor rotates at an angle speed Ω -Zero. The opening angle of the individual antennae in azimuth is Γ , the opening angle of the antennae in elevation is ϵ , and the depression angle of the antenna's line of sight relative to the horizontal is θ . With rotation of the rotor 2, a circular area 4 on the ground with a strip width SW as in Fig. 1b is illuminated. The areas within the circular area 4 which are momentarily illuminated by the antenna 3 are illustrated by light ovals 5.

Figs. 2a and 2b illustrate in detail the illumination geometry in elevation or azimuth. The inner edge of the illuminated circular area 4 with a strip width SW lies on the ground at a distance R_{G1} from the projected helicopter centrepoint, and its distance between the antenna is R_{S1} . θ_1 denotes the depression angle between the antenna and this point. The values R_{G2} , R_{S2} and θ_2 apply to the corresponding point on the outer edge of the illuminated circular area 4. R_{G0} and R_S apply to the point on the ground in view of the central line of sight of the antenna with depression angle θ . The difference between R_{S2} and R_{S1} is characterized by ΔR_S in Fig. 2.

According to Fig. 3, the strip width of the circular area between R_{G1} and R_{G2} is divided into individual radially identically sized range intervals 6, the radial centrepoints of which lie at the distances R_{G1} , R_{G2} to R_{GN} . The total number of these range intervals 6 is N . This number depends on the minimum radial resolution ΔR_{Smin} .

Fig. 4 illustrates a block circuit diagram of a processor for a ROSAR apparatus, and in the top half of the block circuit diagram are illustrated those modules which are necessary to generate the reference functions, and in the bottom half are those modules which serve to receive signals reflected from the ground. The reference signals and the received signals are correlated in a correlator 7 and fed to a store 8, for example a magnetic tape. An additional display on a monitor is possible.

A geometric module 10 is provided for determining the reference functions, and a module 11 for determining the number of range intervals, a module 12 for stating the individual range intervals, a module 13 for stating the integration time, a module 14 for stating the support points for the reference functions, and finally a module 15 for determining the reference functions from delivered data for the individual range intervals. These reference functions are fed into a store 16 which feeds the reference signals to the correlator 7. The receive signals S_g are essentially treated in a conventional manner. The stored receive signal is fed as an intermediate frequency signal to a quadrature demodulator 21 and processed by quadrature mixing and split into an in-phase component of the echo signal I_e and a quadrature component Q_e of the echo signal. These components are fed to analog-digital converters 22 or 23, to the output of which are applied discrete scanning values i_e or o_e of word length U . These complex echo signals are stored in intermediate stores 24 or 25 which comprise respectively N storage places corresponding with the abovementioned N range intervals. The scanning

values of the intermediate stores are fed to a store 26 for the receive signals, which is itself at the output connected to the second input of the correlator 7.

The operation of the entire processor is controlled by a clock-pulse generator 27, which emits a pulse signal C1 to the modules for generating the reference function, and also to the modules for processing the receive signals and to the correlator.

Fig. 5 illustrates the geometric module 10, i.e. based on the operational values to be calculated by it, which it determines from the input values from which it calculates respective output values. Input values are the altitude above ground H_0 , the depression angle Θ , the opening angle ϵ of the antennae in elevation and the distance of the antenna from the point of rotation, i.e. the length of the rotor blade. Due to the geometric relations illustrated in block 10, initial values as illustrated in Figs. 1 and 2 result, i.e. Θ_1 , Θ_2 , R_{G0} , R_{G1} , R_{G2} , R_{S0} , R_{S1} , R_{S2} , SW and ΔR_S . In the module 11 is determined, from the initial value ΔR_S and based on the listed formulae, the echo duration t_e and the number N of the range intervals within the illuminated strip. For calculation of the echo duration, the antenna characteristic C has to be specified as an input value. The number N corresponds with the number of the resolution cells corresponding with the individual range intervals R_{G1} to R_{GN} in a radial direction on the ground as in Fig. 3.

Module 12 calculates, from the input volume R_{G1} which is offered by the geometric module 10 and the number N from module 11, the actual values for the individual range intervals R_{Gn} , as illustrated in

Fig. 7. The number N of the range intervals is fed to a counter 31 which calculates from the input value n to N a respective output value x_n which is reduced by a value of $1/2$ relative to the input value. The output signals of counter 31 are fed, together with a signal ΔR_{Smin} for a radial resolution and the signal R_{G1} , to a function block 32 where the values R_{Gn} for the individual range intervals are calculated according to the given formula.

These values are fed to the module 13. The module is also fed via a counter 33 a respectively assigned number n of a total of N range intervals, and it calculates from these values and the opening angle Γ of the antenna in azimuth, the length L of the rotor blade and the angular speed Ω_0 of the rotor blade and in accordance with the formulae indicated in Fig. 8 the synthetic aperture S , the integration time T_S and the rotary-angle area α_s of the integration for one of the range intervals, which is shown by way of index n . This index operates from 1 to N .

The module 14 calculates, based on the integration time T_{Sn} for each range interval and the pulse repeat frequency f_p of the radar unit, the number Z_{Sn} of the support points for the reference function during integration, the step width $\Delta \alpha$ of the support values for Doppler scanning and the reference function as well as the total number Z_p of the support points for a full rotation of an antenna. Additional input values are again the total number N of range intervals, which are pulsed to a counter 34 which ensures calculation of the output values for each range interval n . Additional input values are again the angular speed Ω_0 of

the rotor and the image duration T_B . The image duration is the entire time duration during which the environment is illuminated. Its maximum value is set by the circumference of the rotor-blade plane and the rotation speed for one rotation of the rotor.

The number of support points, which depends on the pulse repeat frequency and the integration time, determines the capacity of the store 16 for reference functions. The store is designed for a maximum occurring number of support points, i.e. for a number which is present along the outer strip edge of the circular area to be illuminated. The step width Delta Alpha of the support values is directly associated with this number of support points corresponding with a respective angular area for the integration.

The reference functions S_R can then be calculated in the module 15 as in Fig. 4 and based on formulae shown thereat from the values R_{gn} , Delta Alpha, Z_{Sn} and the antenna height above ground H_0 . The wavelength λ , the rotor-blade length L and the circle number are offered for this calculation. The calculation is carried out in a function block 36 which is additionally fed, via a counter 37, the number n of a respective range interval.

The reference function S_R is composed of a real portion I_R and an imaginary portion Q_R . This applies to each range interval 1 to N , which is expressed by the additional index n . The formulae on which this calculation is based are indicated in function block 36 of Fig. 10 as scanning values characterized by a caret. Calculation of the reference functions is carried out for all range inter-

vals, so that the scanning values are summed via the number Z_S of the transmit pulses.

The reference functions which have been determined for all range intervals are fed to the store 16, the structure of which is diagrammatically shown in Fig. 11a. This store is divided into lines and gaps, and in each line is stored a reference function for a range interval. The number of lines is determined by the number N of range intervals, the number of gaps is determined by the number Z_{SN} of the support points for a considered aperture length. The number of support points is determined by the desired overall angle of sight of the radar unit, for example 180° , when only a detection of targets in forward direction relative to the flight direction of the helicopter is wanted. The capacity K_R is determined by the product of the total number Z_{SN} of support points, by the number Z_A of the scanning values in radial direction and double value of word length U of digitally converted signals, as these are available as complex values.

In a similar manner, scanning values of received signals are accommodated in the store 26 as in Fig. 11b. The storage capacity K_E of the store 26 is determined by the product of number Z_B of transmit pulses in the lateral direction, the number Z_A of scanning values in the radial direction, and again double word length U of digitally converted receive signals.

In the correlator 7, pulsed comparison and complex cross-correlation of real and imaginary values of the receive signals as supplied by the store 26 are carried out for each observed range interval with respective values of the reference functions. In the correlator 7, a respective number of observed

range intervals are entered via a counter 41; in addition, the angular speed Ω -Zero of the rotor blade and the number Z_B of transmit pulses in the lateral direction relative to the number of support values and the respective step width $\Delta\alpha$ of the support values for Doppler scanning and for the reference function are delivered as set values. The correlation results for the individual scans are fed to store 8 or monitor 9 as resulting signals $S_{on}(t)$.

The correlation in real-time for all values of the input parameters is calculated by way of the indicated processor structure. The function calculations can be simplified within the geometric module 10 in the event that the length L of the rotor blade is very small relative to the range R_{G1} on the ground between the antenna's point of rotation and the inner edge of the illuminated strip. This also results in simplified calculation of the reference function which is derived directly from the shown formulae. From there, a first approximation by way of a simplified circuit can be made for calculating the reference function and for the correlation, which is illustrated by block 51 in Fig. 13. Furthermore, if R_{G0} becomes very large relative to L and also relative to the height H_0 of the antenna above ground, then the shown formulae can be further simplified. In this case, the circuits for generating the reference function can be solidly wired; they are illustrated by the function block 52 in Fig. 13. The aforescribed complete solution has to be applied only in other cases, i.e. essentially for the detection of targets at close range. When using the ROSAR unit in a helicopter, for example as a navigational aid, then the

major portion of all navigational tasks can be accomplished by approximation solutions, i.e. essentially with solidly wired circuits.

The formulae for the reference functions show that the latter is dependent on both the angle speed of the rotor blade and the height above ground. The freedom straight of the rotor-blade seats during circular movement are radial deviations from the circular path, altitude deviations and twists around the rotor axis. In addition thereto, there may be a non-constant angle speed. The axial twist and the radial deviation are essentially negligible as long as the rotor blade is well balanced. Thus, essentially only the elevator move of the rotor blade and the deviation from a constant angle speed remain for correction of the reference function. For the purpose of detecting these two values, the blade tips are provided with a respective kinematic sensor 61 of two acceleration sensors 62 and 63, and the elevator move is determined by way of the acceleration sensor 62, and deviations from the constant angle speed by way of the acceleration sensor 63. Temporal fluctuations of the antenna height above ground can be detected by doubled integration of the signals detected by way of the acceleration sensor 62, whereas deviations of the circular frequency are determined by simple integration of the signals of the acceleration sensor 63 divided by the rotor-blade length. These time-dependent corrections are used in the equation for the reference function in place of thereat available constant values H_0 and Ω_0 .

It has been assumed in the above description that both the transmit antennae and the receive antennae are placed on the blade tips of the rotor. It is

quite possible to transfer energy required for operation of the transmit antennae from the helicopter fuselage to the antennae by way of rotary coupling. However, it is also possible, as is illustrated in Fig. 15, to solidly mount the transmit antennae 71, for example, on the rotor masts of the helicopter and to integrate only the receive antenna 72 into the blade tip of the rotor 2. As the Doppler information is now produced only via the rotating receive antennae, but not additionally via the transmit antennae, the aforescribed formulae, with otherwise unchanged parameters relative to the Doppler information, can now be divided by the factor 2.

The energy transfer between receive antenna 72 and the evaluation circuit 73 of the ROSAR unit is wireless and preferably opto-electronic. For this purpose, the receive antenna is connected to an opto-electronic coupler 74 which converts the electrical signals of the antenna into optical signals, which are transmitted via optical fibres 75 within the rotor blade and which co-operate in the area of the rotary axis of the rotor blade with a photo-detector arrangement 76. The photo-detector arrangement 76 is associated with an arrangement 77 of opto-electronic couplers which convert the light signals into electrical signals and feed them to the evaluation circuit 73. The energy transfer between fuselage and antenna, for example for the purpose of supplying the electro-optical coupler 74, is carried out wireless, for example by means of a circular slot line or a laser arrangement, which are not illustrated. In the latter case, the arrangement 76 also includes active laser-emitter diodes, the light of which is coupled into the op-

tical fibres 75 and in the area of the blade tip converted back into electrical energy for the optoelectronic coupler 74. This is diagrammatically illustrated in Fig. 16. Laser radiation emitted by the laser diodes of the arrangement 76 is transmitted via a lens arrangement 78 in the area of the rotary axis of the rotor into the blade where it is received by way of a laser diode 79 and in an optoelectronic converter 80 converted back into electrical energy which is delivered to a receiver 81 of the receive antenna 72 and to the optoelectronic coupler 74. The receive signals of the antenna 72 are fed to the receiver 81, then optoelectronically converted in the coupler 74 and modulated in a modulator 82. These modulated signals are radiated by a diode 83, focused via a lens arrangement 84 and directed toward the receive diodes of the photo-detector arrangement 76.

The transmit antenna, which is fitted to the helicopter fuselage, and the receive antenna are to have essentially identical antenna diagrams and should have, for example, a horizontal opening angle of 180° . Due to this characteristic of the transmit antenna, only an area ahead of the helicopter can be imaged. During imaging, the signals of the kinematic sensor 61 are fed to the evaluation unit 73 and used for correcting the reference functions. Equally, the receive signal is converted into an intermediate frequency in coherence with the emitted transmit frequency and transferred by way of the light modulator and the laser transmit diode via the laser-transmit path onto the photo-detector unit 76. Thus, the evaluation unit 73 can be fed both the total signal received from the receive antenna 72 and the cor-

recting signals for the reference functions for half a rotation of the rotor blade.

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Patent Claims

- 1: A radar unit comprising at least one transmitter and one receiver, the at least one antenna of which for transmitting and receiving radar pulses is arranged at the end of a rotary arm, a device for demodulation and intermediate storage of received signals, devices for forming and storing reference functions in dependence on the illumination geometry of the radar unit of measured range intervals, rotary angle ranges, transmit pulses as well as the height above ground of the rotating antenna, as well as with a correlator for correlating the received signals with the reference functions and an indicating device for the correlation result, **characterised in that** the devices for forming the reference functions comprise the following modules:
- a) a geometry module (10) which calculates from the aperture and depression angle (ϵ , θ) of the antenna (3), the length (L) of the rotating arm and the height (H_0) above ground of the antenna (3) the width (SW) of a range strip (4; $R_{G2} - R_{G1}$) illuminated by the antenna and the range difference (ΔR_s) between the beams (R_{s2} , R_{s1}) from the antenna (3) to the inner or outer illuminated strip edge;
 - b) a circuit (11 to 15) for division of the illuminated strip (4) into a specified number



(N) of range intervals ($6; R_{g1}$ to R_{gN}); as well as

- c) a module (15) for forming the reference function (SR) for the individual range intervals ($6; R_{g1}$ to R_{gN}).

2: A radar unit according to claim 1, **characterised in that** the circuit (11 - 14) for division of the illuminated strip (4) comprises the following modules:

- a) a module (11) for calculating the number (N) of range intervals ($6; R_{gN}$) within the illuminated strip (4) by division of the calculated range difference (ΔR_s) between the beams (R_{s1}, R_{s2}) from the antenna (3) to the inner or outer strip edge and the desired radial resolution (ΔR_{smin});
- b) a module (12) for calculating the ranges to the interval centre (R_{gN}) within the illuminated strip (4) based on the number (N) of range intervals;
- c) a module (13) for calculating the integration time (T_{sN}) for the individual range intervals; and
- d) a module (14) for calculating the number (Z_{sN}) of the transmit pulses relative to the number of support points for the reference functions (S_R) and the rotary angle range ($\Delta \alpha$) for distances to the interval centre (R_{gN}) due to the integration time.

3: A radar unit according to claim 2, **characterised in that** the module (11) for calculating the number (N) of range intervals ($6, R_{gN}$) additionally



calculates the echo duration (t_e) to $2 \Delta R_s/C$, where C is the speed of light.

- 4: A radar unit according to claim 2, **characterised in that** the module (12) for calculating the ranges to the interval centre (R_{gn}) comprises a counter (31) which is fed the range intervals, and a function block 32 which calculates from the output signals (N to x_n) of the counter 31, the range (R_{g1}) on the ground up to the inner edge of the illuminated strip (4) and the desired radial resolution (ΔR_{smin}) the ranges (R_{gn}) to a respective interval centre as

$$R_{gn} = R_{g1} + X_n \times \Delta R_{smin}.$$

- 5: A radar unit according to claim 2, **characterised in that** the module (13) for calculating the integration time (T_{sn}) comprises a counter (33) which is fed the number (N) of range intervals and which outputs the number (n) of a respective range interval (R_{gn}), and that the module (13) calculates from this number (n) and a respective range interval (R_{gn}), with the aid of the aperture angle (γ) of the antenna, the length (L) of the support arm (2) and the angle speed (Ω -Null) of the antenna (3), both the integration time (T_{sn}), the synthetic aperture (S_n) and the rotary angle range (α_{sn}) of the antenna for each range interval (R_{gn}) as

$$S_n = \gamma \times L \times (1 - L/R_{gn}) \quad (a)$$

$$T_{sn} = \frac{\gamma \times (1 - L/R_{gn})}{\Omega - \text{Null}} \quad (b)$$

$$\alpha_{sn} = \gamma \times (1 - L/R_{gn}) \quad (c)$$

- 6: A radar unit according to claim 2, **characterised in that** the module (14) for calculating the num-



ber (Z_{s_n}) of transmit pulses and the rotary angle range ($\Delta\alpha$) comprises a counter (34) which is fed the number (N) of ranges (R_{g_n}) and which outputs the number (n) of respective range intervals (R_{g_n}), and that the module (14) calculates from this number, the integration time (T_{s_n}) and the pulse-repeat frequency (f_p), with the aid of the angular speed (Ω_{Null}) of the antenna (3), the number of support points (Z_{s_n}) and the angular step width ($\Delta\alpha$) as

$$Z_{s_n} = f_p \times T_{s_n} \quad (a)$$

$$\Delta\alpha = \Omega_{\text{Null}}/f_p \quad (b)$$

- 7: A radar unit according to one of the above claims, characterised in that the module (15) for determining the reference functions (S_R) comprises a counter (37) which is fed the number (N) of range intervals (R_{g_n}) and which outputs the number (n) of a respective range interval (R_{g_n}), and that the module (15) calculates from this number (n), a respective range interval (R_{g_n}), the angle step width ($\Delta\alpha$), a respective support point (Z_{s_n}) and the height (H_0) of the antenna (3) above ground, with the aid of the wavelength (λ) and the length (L) of the support arm (2), the real portion (I_{R_n}) and the imaginary portion (Q_{R_n}) of the reference functions (S_R) as

$$I_{R_n}(t) = \sum_{m=1}^{Z_{s_n}} \cos(4\pi/\lambda) \sqrt{\frac{L^2 + R_{g_n}^2 - 2L \times R_{g_n} \times \cos(m \times \Delta\alpha)}{H_0^2}}$$



$$\begin{matrix} Z_s \\ \hat{Q}R_n(t) = \sum_{m=1} \sin(4 P / \text{Lambda}) \sqrt{\frac{L^2 + R_{gn}^2 - 2 \times L \times R_{gn} \times \cos(m \times \text{Delta Alpha})}{H_0^2}} \end{matrix}$$

- 8: A radar unit according to one of the above claims, **characterised in that** the support arm (2) for the antenna (3) has in the area of the latter a kinematic sensor (61) for determining altitude fluctuations of the support arm (2) in the region of the antenna (3) and fluctuations in angle speed of the support arm, and that from the measured accelerations in the reference functions is introduced a thereat assumed constant altitude (H_0) and angle speed (Ω_{Null}) as a variable.
- 9: A radar unit according to claim 8, **characterised in that** the kinematic sensor (61) comprises two acceleration sensors (62, 63), which are sensitive in two vertical directions to each other, and that the first acceleration sensor (62) is oriented in a direction which determines the altitudinal flap of the support arm (2), and the other acceleration sensor (63) in the peripheral plane of the support arm (2).
- 10: A radar unit according to one of the above claims, **characterised in that** only the receive antennae (72) are arranged on the rotary support arm (2), and that the transmit antenna (71) is fixed relative to the rotary axis of the support arm (2) on the rotor mast.
- 11: A radar unit according to one of the above claims, **characterised in that** the energy transfer to the rotating antennae (3, 72) and the signal transfer from the rotating antennae (3,



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72) is carried out contact-free via the rotary axis of the support arm (2).

- 12: A radar unit according to claim 11, **characterised in that** the energy transfer to the rotating antennae (3, 72) and the signal transfer from these antennae (3, 72) is carried out with the aid of an opto-electronic coupling arrangement (74, 76, 77).