Mobile X-band Direction Finder

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***Abstract* — A compact X-band direction finder is presented in this paper. Algorithm of the system operation using the "null-amplitude" technique is described in detail. Based on the results of model experiments the resolving capacity of the direction finder prototype are determined.**

I. INTRODUCTION

Nowadays, the different direction finder systems operating at frequencies f=1GHz and higher are described in many papers [1-6]. However, the advancement to the state-of-the-art backbone links compels moving to the higher frequencies. To this end, the broadband mobile direction finder systems are in great demand. In our previous papers [7-9] we have declared a novel design of the compact broad-band direction finder operating in the X-band and using "null-amplitude" technique. The novelty of this finder is an employment of the cylindrical monopole antenna as a primary source of the reflector antenna. The optimal parameters of both the monopole antenna and the reflector antenna in whole have been determined in [7, 8] while the bearing features of the local SHF sources have been highlighted in [9].

In this paper we describe in detail the algorithm of radiation sources bearing by using the aforementioned direction finder and discuss the results of model experiments.

II. DIRECTION-FINDER PROTOTYPE

The design of direction finder antenna is shown in Fig.1. Antenna comprises the main parabolic reflector with the aperture radius of 80mm and primary source, located in the reflector focus equals to 55mm. The main feature of this antenna is the use of primary source as the cylindrical monopole antenna (the monopole height is 22.5mm and the ground plane radius is 22.5mm) optimized from the point of view the reflector blockage and the utilization factor of its surface.

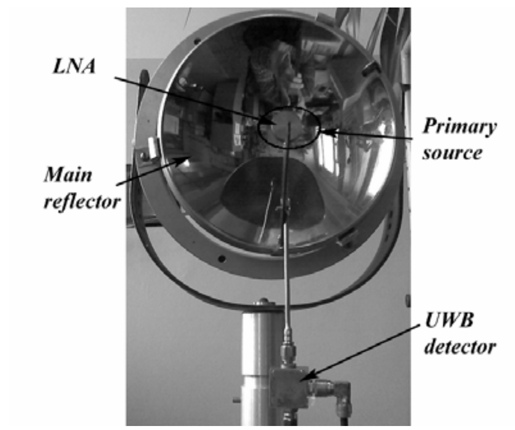

Fig. 1. Direction finder antenna prototype

The conceptual block-diagram of the direction finder system is shown in Fig. 2.

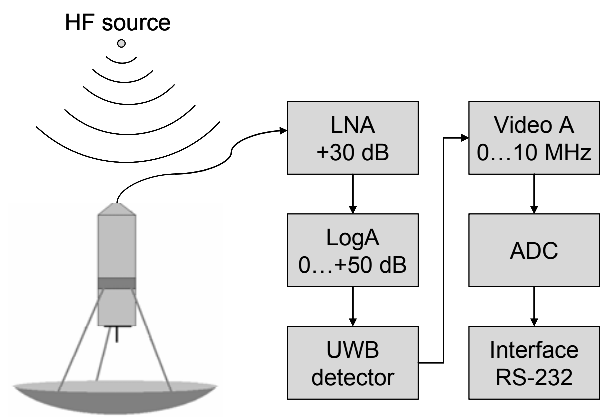

Fig. 2. Block-diagram of the direction finder

In order to realize the reflector-type antenna operation in the receiving mode we have integrated three-stage HEMT based amplifier in the input antenna circuit that allows us to provide a noise-factor not worse than 0.5dB within the operational frequency band. The first stage of amplifier with the input line-building-out network is similar to that described earlier in [10]. The principal distinction consists in achieving a broader match strip due to the use of state-of-

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the-art notably low-noise transistor Agilent ATF 36077. The signal received from the SHF source enters the aforementioned low-noise amplifier for the signal pre-amplification within the antenna bandwidth. The subsequent logarithmic amplifier realizes the signal amplification to the level to be quite enough for the effective ultra wideband video detector operation. The latter is a high-sensitive zero-bias diode HSMS-2850 having the 20dB dynamic range and output video-signal band 0 – 10MHz.

Next wideband low-noise video amplifier increases the information signal up to the level required to the flash encoder operation (around 2.5V). After video-amplifier the information signal enters the interface, which serves for the registration, numeralization, and displaying the level of receiving signal, and than on a working board of the control unit [9].

It is worth noting that the metal shield amplifying circuits are located directly behind the ground plane of the monopole antenna thereby being plug-compatible with the primary source. At the same time the ultra wideband detector and following the wideband low-noise video amplifier, which is able to support a detection of both the monochromatic signals and the amplitude- and pulse-modulated signals, are constructively located on the antenna holder.

The manufactured and optimized reflector antenna produces the mono-beam conic radiation pattern in the frequency band 6GHz – 11GHz with the elevation angle of the peak directivity $\theta=10^0$ (Fig. 3).

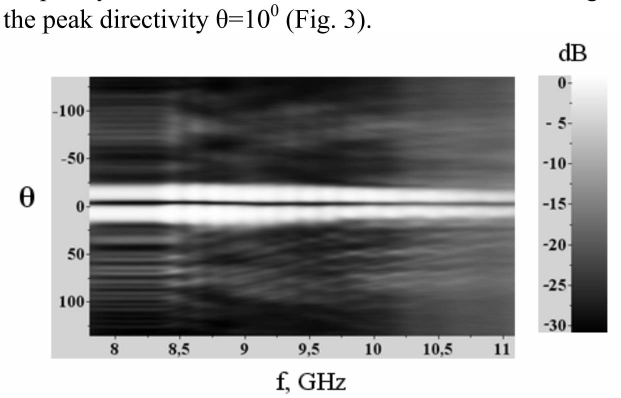

Fig. 3. Radiation pattern of the reflector antenna

By analysing a radiation pattern of the direction finder antenna within the limits of the operational frequency band we can conclude that the experimental radiation patterns are more narrow than calculated ones. A typical radiation pattern at the fixed frequency is presented in Fig. 4. As can be seen from this figure we also note that the side lobe level of the measured radiation pattern does not exceed -20dB. It is worth noting that the principal characteristic of the direction finder using the "null-amplitude" technique is the angular domain of the "global" minimum of the radiation pattern along the antenna axis. This angle $\Delta\theta'$ is determined by the two positions of the antenna relative to the stationary receiving antenna when the signal amplitude increases on 3dB in comparison with the signal level in the "global" minimum and equal to $2\Delta\theta'=1.5^0$ in this case.

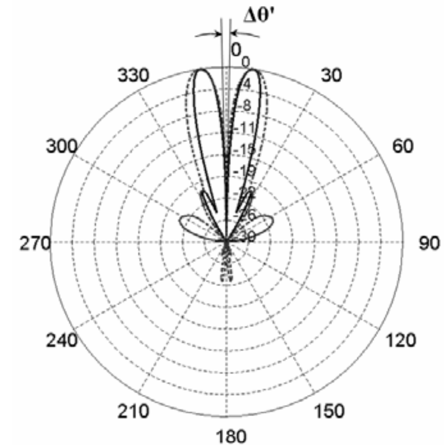

Fig. 4. Calculated (dotted line) and measured (solid line) radiation pattern of the reflector antenna at f=10GHz

As the radiation pattern looks like a "bell" shape we imitate a bearing process on the front panel of the control unit by a suitable arrangement of the light emitting diodes (LED) which connected with the level of received signal (Fig. 5).

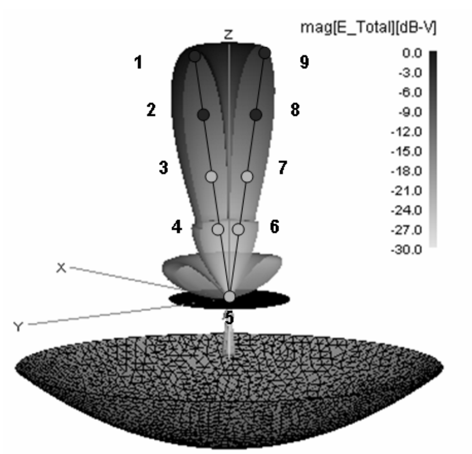

Fig. 5. Conformity of the bearing process indication

III. The Bearing Algorithm

The bearing algorithm is as follows. It is quite clear that preliminary scan of the space area of interest is carried out. Let us assume that only one SHF source is located in the space. In this case we shell detect this source when it will hit the main lobe of radiation pattern of the direction finder antenna. At that, the source bearing will be determined by the antenna position corresponding to the "global" minimum of the received signal. Below the bearing algorithm is described in detail by means of the diagram shown in Fig. 6.

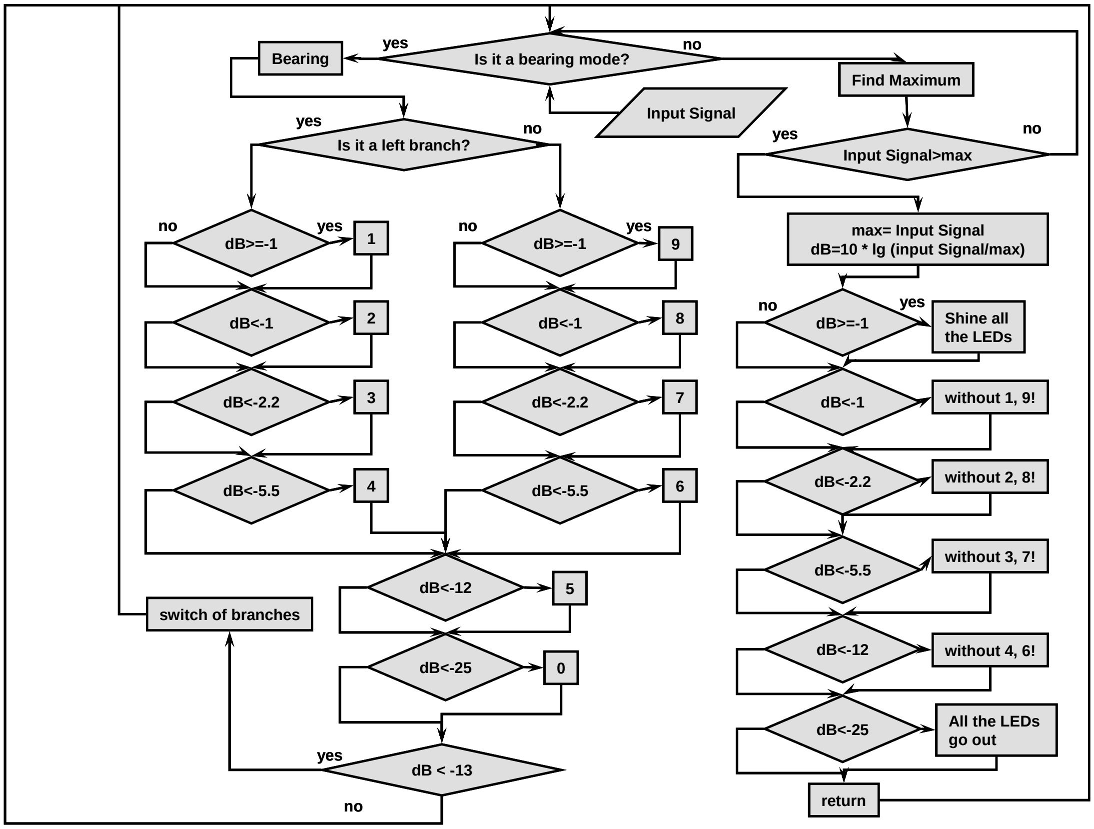

Fig. 6. Block-diagram illustrating a bearing algorithm

Two operation modes called the "Search mode" and the "Bearing mode", respectively, are realized here. Under the finder operation in the "Search mode" the angular domain of the source location and its power level are determined.

In the "Search mode" operation and under the external sources failing all the LED's on the front panel of the control unit frequently blink thereby indicating the availability of both the internal equipment noises and the environment background noise. The source signal appearance is indicated by the ignition of all the LED's and the maximum power level of the received signal with the value 0dB remain in the microcontroller memory. Any deviation of the direction-finder antenna from this position will lead to the signal power decrease and will be accompanied by LED's switching off in pairs top-down according to the introduced normalization (Fig. 5). In the process of consequent scan of the space within the angular domain of the revealed source, every such a scan is completed by the memorization of the maximum signal level. Thus, in the 'Search mode" operation the angular domain and the maximum signal level of the external SHF source are determined.

The parameters noted above are the initial ones for the "Bearing mode" operation. In this case a one of the upper two LED's on the working board of the control unit is shined. Let us propose that with the antenna rotation from the aforementioned initial position the received signal decreases by accompanied with the alternate LED's switching top-down so long as the lower LED goes out. These conditions correspond to the drift of antenna from the source. After that the antenna goes back to the initial position of the maximum signal reception and turns in the opposite direction (i.e., to the source). In this case the LED's will alternate switching along the appropriate branch of the symbol V on the working board of the control unit. After the antenna passes the point of the null signal reception, the LED's begin to shine in turn on the second branch of the symbol V on the working board of the control unit right up to the topmost LED.

Thus, the source bearing corresponds to the antenna position when the lower LED shines on the working board of the control unit.

Let's now determine the conditions of the precise bearing angle determination. First of them consists in that the received signal power level for the antenna position corresponding the null reception must decreases to the signal level given in advance (in our case this upper level of the global minimum is determined by the radiation pattern of antenna and equal to -13dB). However, when holding this condition only the bearing uncertainty would occur in view of the chaotic LED's switching between the left and right branches of the symbol V (the side lobes availability or the loss of signal at the drift of antenna from the source). In this respect the second condition is the source must remain in the main lobe of the radiation pattern of antenna in the bearing process. Therefore, the complementary variable max_dB with the initial value of -100dB is introduced in the program and we assign in advance the condition max_dB>-5.5dB determined experimentally. Only in the case of the signal level exceeding -5,5dB again and subsequent its decrease to the level <-13dB, we will observe the LED's switching from the one branch to another one. It means that at first the antenna scan should be realized in the one selected direction right up to the total signal loss and after that only the antenna should turn in the opposite direction.

If the signal level (in the process of antenna scanning) becomes less than -12dB, the lower LED shines on the front panel of the control unit and with the subsequent signal level increase the LED's will be alternate shined on the another branch. It is worth noting that the lower LED goes out when the signal level becomes <-25dB. Just this condition corresponds to the signal loss. Thus, this is the lower limit of the received signal level at which all the LED's go out.

IV. Model Experiments

The first model experiments we carried out with an open-ended X-band waveguide, which was located at the distance 100m from the direction finder prototype (Fig. 7). By using the algorithm noted above we have determined a direction on the SHF source with an evaluation accuracy of the source bearing equal to $2\Delta\theta'=1.5^0$. We note that a noise-factor of the direction finder integrally (excluding the direction finder operation in zenith directly) averages 2 – 4dB depending on the elevation bearing.

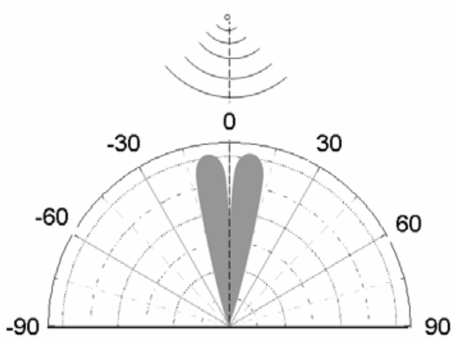

Fig. 7. Bearing a single SHF source (f=10.3 GHz)

The most important characteristic of any direction finder is the resolving capacity. By taking into account the radiation pattern shape of our antenna, we are able to evaluate the limit space resolution of the direction finder prototype in case of bearing two external sources. To this end we carried out the model experiments with two identical SHF sources as the open-ended X-band waveguides being 100m removed from the antenna and located in the one plane with the latter. A distance between the sources was changed from 5m to 40m. From these experiments it has been found that the sources are to be discriminate with evidence if the minimal distance between them becomes more than 34m. Hence, the limit space resolution of the direction finder prototype corresponds to the sources location in the maximum of the radiation pattern of antenna. In this case the observation angle of these sources $\theta_b=20^0$ (Fig. 8) is in the true compliance with findings depicted in Fig. 3.

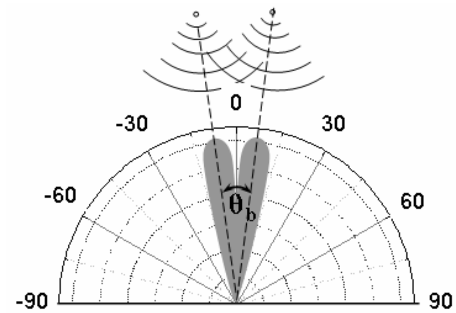

Fig. 8. Bearing the two SHF sources (f=10.3 GHz)

But for all that we have to take into account that a polarization of the source radiation will play a vital part in the bearing process. In spite of the fact that the direction finder antenna is able to receive the SHF signal with an arbitrary polarization, such an immovable antenna will be blind to the source having E_φ-polarization and moving in the same plane.

V. Conclusion

Mobile X-band direction finder has been presented in this paper. The main features of the bearing algorithm have been described in detail. As a result of model experiments the resolving capacity of the direction finder prototype has been determined. The proposed direction finder seems to be very attractive for different wireless applications.

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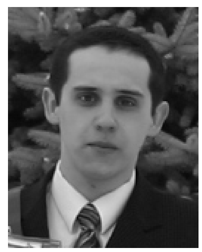

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