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U.S. ARMY FOREIGN SCIENCE AND TECHNOLOGY CENTER

TECHNOLOGY AND METHODS OF ELECTRONIC WARFARE

COUNTRY: EAST GERMANY

TECHNICAL TRANSLATION

22

TECHNICAL TRANSLATION

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TECHNOLOGY AND METHODS OF ELECTRONIC WARFARE

(Technik und Methoden des dunkelektronischen Krieges)

by

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TECHNOLOGY AND METHODS OF ELECTRONIC WARFARE

2.2.1. Radio location protective coatings

War technology in military objectives can be masked from radio location observation by using special protective coatings.

It is exceptionally difficult to arrange rockets, airplanes, ships, and other pieces of military equipment in such a way that they are invisible to radio location observation. Maximum perception distance $D_{auff\ max} = k \cdot \sqrt{\sigma_L}$ (?) changes only in proportion to the square root of the effective target reflection surface. For example, reducing the reflected power by half only decreases perception distance of ground targets by 10 to 20%. These difficulties are increased by the fact that modern radio location devices work on different frequencies. Therefore the targets must be protected in a wide frequency range.

At the present time two kinds of material are used to decrease reflection intensity: absorption materials and interference materials.

Absorption coatings must meet two requirements:

In the first place they must not reflect electromagnetic waves which hit them, and must also completely absorb the waves which originate inside the material itself. To produce a material which fulfills both requirements it is extremely complicated from a technical point of view. It is known that for the reflection factor of an electromagnetic wave on a level flat surface with constant ε_r and μ_r, the following formula is valid:

$$K = \frac{\sqrt{\frac{\varepsilon_r}{\mu_r}} - 1}{\sqrt{\frac{\varepsilon_r}{\mu_r}} + 1}.$$

ε_r, μ_r are the relative dielectric constant and relative permeability constant.

It may be known from this formula that no reflection occurs for $\varepsilon_r = \mu_r$. In wide band protective coatings, dielectrics can be used as absorbers, where $\varepsilon_r \approx \mu_r \approx 1$. In order to prevent a reflection, the absorbing material must have a dielectric constant which comes close to that of air ($\varepsilon = 1$). Rubber, polystyrol foam and other porous materials have this quality.

The absorbing action of these coatings is based upon the fact that the high frequency energy is transformed into heat. The heat is produced by the weak eddy currents induced and by the dielectric loss. The acceptable amount of energy depends on the maximum permissible temperature of the absorption coating.

Coal dust, the proportion of which increases in the layer from outside to inside, is used as a suitable absorber. Good energy absorption is obtained by multilayer protective materials with damping increases along with the increasing impressions of the wave in the material. This is the reason why the concentration of the absorber (e.g. coal dust) is greater in every layer.

Through the use of multilayer protective materials, the frequency range is similarly increased. The frequency range within which energy absorption occurs depends upon the thickness of the material. The main defect of multilayer protective materials is found in its great thickness and mass. A square meter of multilayer protective material at the present time has a mass of 2 to 6 kg.

In order to diminish the reflex radiation intensity of radio waves, the surfaces of the protective materials are given a waffle shaped structure in which the elements protruding from the even surface have the shape of a pyramid or a cone (Fig. 2.59). Protective materials with a waffle shaped surface structure reduce the reflex radiation intensity, because the radio waves have essentially more contact with the protective layer through the successive reflections on adjacent points and are thus more intensively absorbed (2.60). In order to obtain more reflections, the pyramids are made very sharp. Some waffle shaped protective layers reduce the reflection intensity for electromagnetic waves and the centimeter wave range by 90% and more.

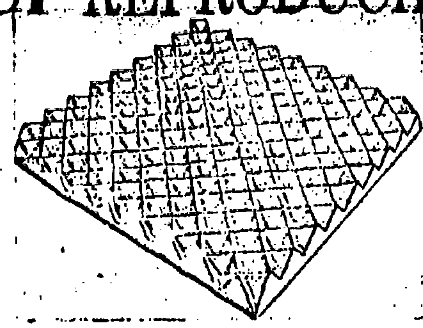

Figure 2.59. Surface structure of a protective layer

Absorbing protective materials have the most varied structure and electrical value. Thus, e.g., a protective layer of 12.7 mm thick fiberglass absorbs almost 99% of occurrent energy in the wave range from 1 to 77 cm. Fiberglass has adequate elasticity at its disposal, is resistant to the influences of weathering and is inflammable. Radio location protective coatings for flying machines are produced from ceramics (ferrites), which are applied as a thin layer to the objective to be protected. These absorb the energy of electromagnetic radiation in the centimeter and meter wave range.

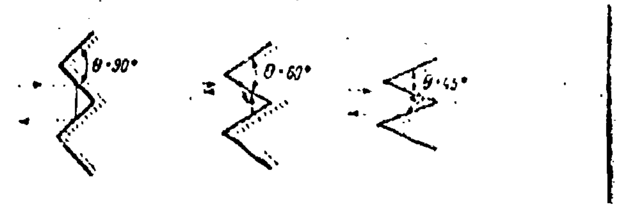

Figure 2.60. Reflection on waffle shaped surfaces

Abroad work is going on to produce protective materials which convert electromagnetic energy into chemical energy. A great deal of energy is also being devoted to researching plasma as an absorption medium.

For application under stationary conditions, the absorbing materials are produced from matted fibers which are saturated with a mixture of neoprene (a kind of rubber) and conductive carbon black. Compositions of wool and iron filings are also suitable as absorbing material. A lining of corrugated cardboard is also worked into this material. On piercing the material, the radio waves are dispersed by the metallic particles and absorbed by the wool. Absorption mats of this type are 40 to 50 mm thick and can damp reflections 20 to 50 times.

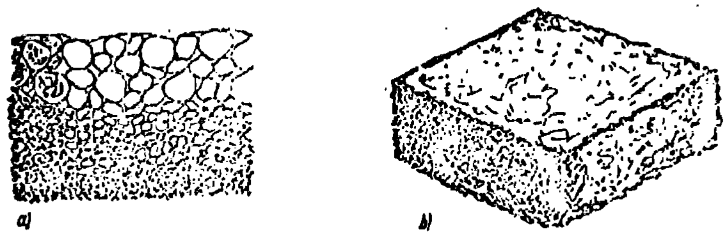

Figure 2.61. Absorbing materials a) triple layer component; b) rubber saturated wool matting.

Wide band absorbing materials, which consist of a mixture of porous rubber and coal dust or of polystyrol foam with a layer of carbon, are suitable for radio location masking of immovable or not very moveable objectives and sites (buildings, harbors, canals and ship superstructures). These protective layers have a waffle shaped surface so that the reflection intensity does not depend very much upon the angle of collision. The performance reflection factor of such protective materials does not exceed 1%. The effective reflection surface of such protective objectives is reduced more than 100 fold and its perception distance reduced to one third.

Even buildings made of porous concrete with an addition of graphite or multilayer material furnish only weak radio location contrasts. The coatings of these construction materials (Fig. 2.6ia) have pores and grains of different sizes. The grains of the construction material become finer from outside to inside and are reduced from 20 mm grain diameter in the outer layer to 0.7 mm grain diameter in the inner layer.

A triple layer protective material absorbs the electromagnetic energy with the cavities of its outer layer. The radio waves which have penetrated the second layer are partly absorbed into its pores and partly broken up and reflected back to the outer layer. The third, fine-grained layer reflects very strongly. Thus the energy which has reached this point is damped again in the pores of the layers it now goes through for the second time.

Interference materials. Their method of operation is illustrated by Figure 2.62. Damping takes place by interference with the waves reflected to two upper surfaces. If the protective material has a thickness which is equal to one quarter the wave length or its odd-number multiple, the wave rhythms reflected on the two surfaces are opposed in phase and cancel each other at equal amplitude. The thickness l of the interference layer is found from

$$l = \frac{\lambda}{4}\sqrt{\frac{\epsilon_r}{\mu_r}}. \qquad (59)$$

Good results can only be obtained with interference layers in a small frequency range. With an increase in wave length, the thickness of the protective layer must be increased.

This type of protective material reduces the reflected energy to several tenths, but work well only if the waves hit it perpendicularly. If the waves coincide from other directions, the absorption intensity is severely diminished. For non-perpendicular occurrent waves, the reflection factor K is a function of angle of attack ϕ.

$$K = \frac{1 - \cos\varphi}{1 + \cos\varphi} \qquad (60)$$

Metal nets, which can be applied at a distance of one quarter wave from the object to be protected, or a dielectric material, which is applied to a metallic surface in the thickness of a quarter wave, serve as interference materials.

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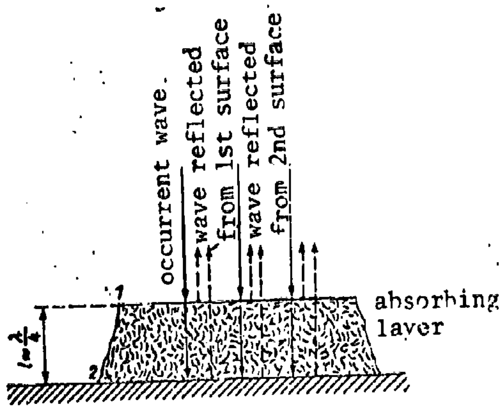

Figure 2.62. Method of operation of an interference material.

Similar protective layers were used by the fascist navy during the second world war to mask radio location of snorkels and submarine periscopes (Figure 2.63). When interference layers are used, only one four-hundredth of the occurrent energy in the wave length range from 112 to 195 cm is again given off as radiation; in this way the perception distance of masked objectives is reduced to about one quarter.

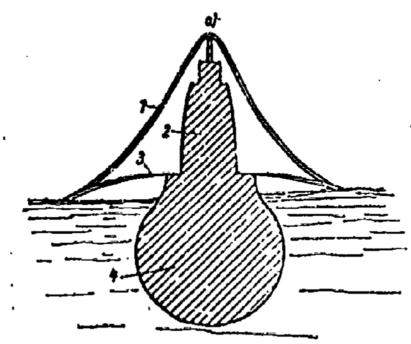

Figure 2.63. Radio location masking of a submarine: 1) masking; 2) power; 3) masking; 4) body of boat.

In West Germany an absorbent masking tissue has been developed with a layer shaped lattice structure. The lattices of the tissue are filled with a mixture of graphite powder and a binder. The tissue consists of three or five layers with lattices of different sizes in each layer. It is suggested that tanks, cannons, rocket launching ramps, airplanes on airports and other military equipment on the battlefield or behind the battle zone be masked with this type of tissue.

The use of weakly reflective construction sheets.

The reflection properties of military equipment also depend on its shape. Maximum reflection on the sides turned away from the radio location device is attained, e.g., with the inclined plane, the pyramid and the cone.

Objects with a surface free of angles, cylinders and smooth surfaces perpendicular to the occurrent direction of the waves, offer minimum reflection.

In order to find the weakest reflecting construction form, models are used which are irradiated with light or millimeter waves.

2.3. Infrared reaction

Infrared rays are electromagnetic waves which are irradiated from every body which has a specific temperature above absolute zero. The infrared range includes wave lengths from 0.77 to 340 μm. Infrared radiation can only be perceived with special infrared receivers.

Infrared instruments are inserted into the target seeking systems of rockets, in observation devices and in devices for obtaining cartographic round pictures. Beyond that infrared technology is widely distributed in airplane and rocket defense.

The strongest sources of infrared radiation in military technology are rockets, jet propelled aircraft, ships, tanks and other objects. The main sources of heat radiation of rockets and airplanes are the gas trail and the covering skin which is severely heated during flight in the atmosphere. Infrared radiation which is irradiated from rocket operation during its active flight phase can be perceived from distances of more than 1000 km. The radiation given off as a result of aerodynamic heating of the skin of airplanes and rockets can likewise be discovered at a great distance.

The main sources of infrared radiation from warships are the openings of the exhaust stacks and flues. The radiation from ships can be perceived up to 10 km away. The main radiation source of industrial objects (factories,

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thermal power stations) are the flues.

Infrared masking consists of adapting the character and amount of heat radiation of the object to be masked to the radiation of the surroundings. This task is predominately solved by reducing the heat radiation of the radiating object. In particular the temperature at the openings of flues and exhausts stacks is diminished by reducing their diameter, by cooling an by using screens or a heat insulating sheet. For example, the British airplane Buccaneer-2 makes use of such an infrared screening (Figure 2.61).

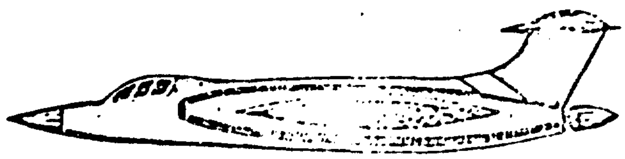

Figure 2.64 . Screening the infrared radiation of the exhaust radiation.

Another method of heat-masking objects on land and sea is the laying of smoke curtains which provide absorption properties in the spectral range of 3 to 5 μm. In addition to these, rain and snow, as well as smoke produced from titanium tetrachloride, exhibit good absorption qualities.

Since infrared radiation sources have a great radiation output, strong radiation sources are also necessary to imitate them.

Infrare' ... itors, which can be used as heat decoys, reach a radiation ... put ... to 3 μm range of about 2.5 kW within a few seconds. Gene ... type can be installed as decoys. In the United States a ... ed guided rockey, the TDU-12/W Skydrar (?), is used as ... t has a two stage driving mechanism, which makes possible ... during which distances up to 48 km can be covered. The ... long, has a diameter of 165 mm and can be launced from ... anes.

... infrared radiation of ships is achieved with heat deco ... temperature lies higher than that of the flue openings of ... asked. Such a target is, e.g., an aluminum reflector a ... f which lie electrically heated small chromium nickel tu ... temperature reaches 750° centigrade, the irradiated output reaches 1 kW for 1 m tubelength.

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Figure 2.65. Methods of infrared reaction: 1) target seeking rockets with an infrared heat; 2) smoke curtain; 3) infrared observation devices; 4) rockets which disperse infrared reflectors; 5) infrared receiver; 6) pyrotechnic media; 7) infrared decoys; 8) seeker head.

In addition light flares launched from the airplane are known which produce a bright flash and a thick cloud of smoke. These light flares guide rockets with infrared seeker heads to themselves. The efficiency of heat decoys is considerably increased in the infrared radiation of the object to be masked is reduced at the same time.

Figure 2.65 shows several possibilities of protecting an airplane from perception with infrared media.

2.4. Radio heat detection finder reaction.

Radio heat direction finders or passive radio location devices assume an intermediate position between radio location and infrared technology.

Radio heat direction finders receive and analyze the millimeter and centimeter waves which every body with a specific temperature above absolute zero irradiates. The intensity of the radio heat radiation depends on the temperature, the dimensions and the kind of irradiating surface of an object, on polarization, on the electrical and magnetic properties of the radiator and on the condition of the surroundings of a radiation source. Sense of the radio heat signals can be irradiated in an extremely wide frequency range but with only a weak output, they can only be perceived by means of highly receptive, wide band receiving devices which can also work under a signal-noise ratio less than 1.

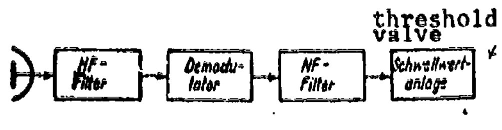
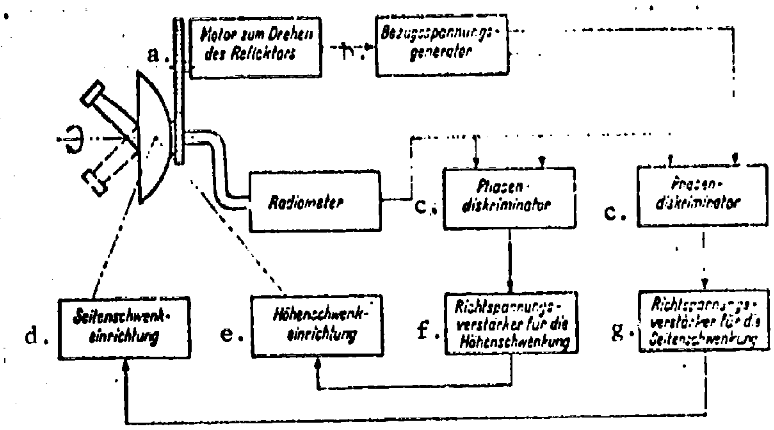


Figure 2.66. Simplified block diagram of a radio meter



a. Peflector turning motor
b. Reference voltage generator
c. Phase discriminator
d. Lateral swivel device
e. High swivel device
f. High swivel directional voltage amplifier
g. Lateral swivel directional voltage amplifier

Figure 2.67. Block diagram of a radio heat direction finder.

The apparatus which perceives and receives radio heat apparatus is called a radio meter. The block diagram of the simplest radio meter is shown in Figure 2.66.

The finding methods and the construction of radio heat direction finders are similar to the methods and hookups in radio finding and in radio location technology. The block diagram of a radio heat direction finder with conical space investigation is shown inFigure 2.67.

Because of the high receptivity of the receiving apparatus, radio heat direction finders are also extremely sensitive to disturbance. However, because they cannot be perceived, deliberature disturbances are impossible. The work of radio heat direction finders can only be disturbed or made difficult by broad band disturbances and similitude of the proper radiation of the targets to the radiation of the surrounding land. In the American army, e.g., the forces and means of electronic observation and reaction are carried on by a partial system of the automated guidance system of the ground forces (Figure 4.8). Elaboration of the observation devices and control of the reactive means is successfully automated with the help of electronic computors (ERM) in the guidance centers of the staffs of the various army groups. Here the observation apparatus is also prepared and reactions planned.

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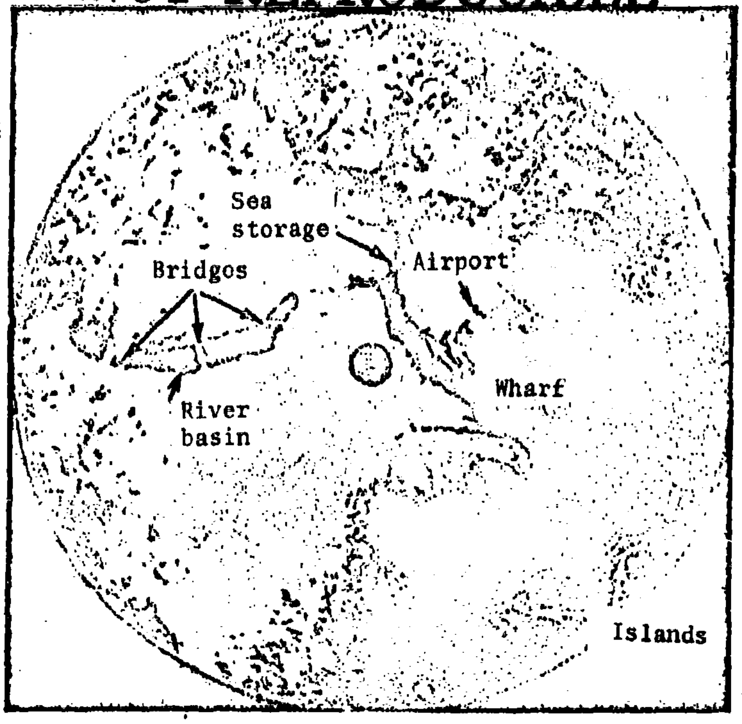

Figure 4.9a. Radio location picture taken from 1200 m high. Length of the observed segment: 9.25 km; width of the antenna directivity: 0.8°; impulse period: 0.25 µs

4.2.2. Radio location masking.

In modern armies radio location masking is given great attention.

Radio location devices are employed, as is known, to a large extent in the observation of ground, air and sea targets. By themselves these are capable of perceiving, even in the complete absence of optic vision, moveable ground and sea targets (tanks, armored troop carriers, motor vehicles, units, ships, surfaced submarines and targets lying within the limits quasi-optical site).

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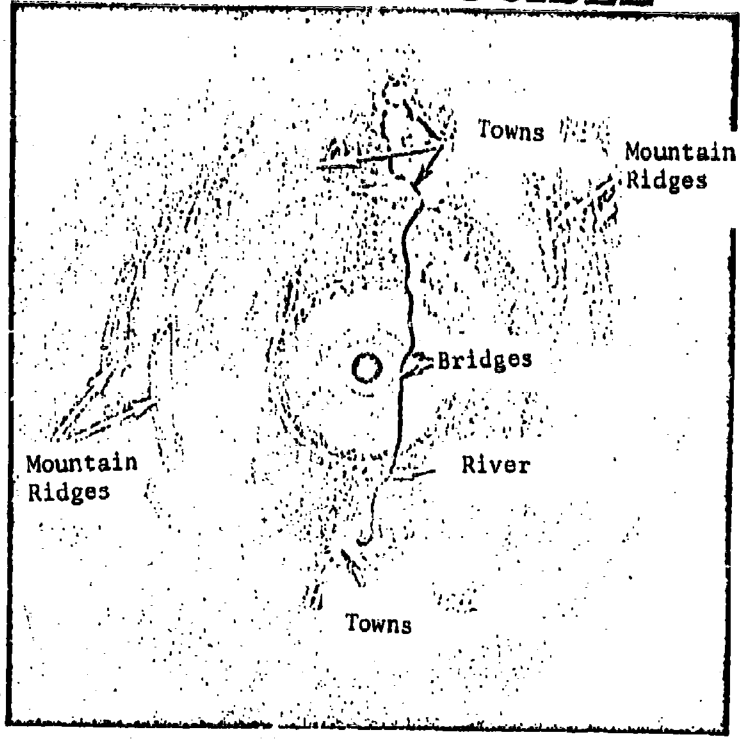

Figure 4.9b. Locational determination according to the form of the surface irregularities. Observation height: 2100 m; length of the section observed: 37 km; width of the antenna directive pattern: 0.8°; impulse period: 0.5 μs.

On the sight apparatus of the panorama radio location devices of airplanes, cities, bridges, lakes, roads, rivers, targets on the water, concrete runways and high tension lines can be clearly observed (Figure 4.9a, b). Objects lying on the ground appear on the radio location sight apparatus of the airplane in the shape of marks with different configurations, in which their brightness depends on the magnitude of the energy reflected by the targets and by the surrounding background. Settlements, bridges and other places intensively reflect the greatest part of the occurrent energy back to the radio location antenna and appear on the screen as bright marks. A flat, untilled piece of land gives a halftone picture, mountain chains form a combination of bright marks and shade, since the non-radiated slopes appear darker than the peaks (Figure 4.10). Mountain slopes lying further away produce a picture similar to a relief map. Water surfaces (rivers, lakes, seas) reflect radio waves like a mirror. For this reason only a negligible fraction of the reflected signal comes back to the radio location position, and the water is to be seen as a dark fleck on the screen. The boundary between water and land shows up most clearly. Concrete airport runways disperse the electromagnetic energy somewhat less intensively than overgrown surfaces. Therefore, like water surfaces, they produce dark flecks on a visible screen.

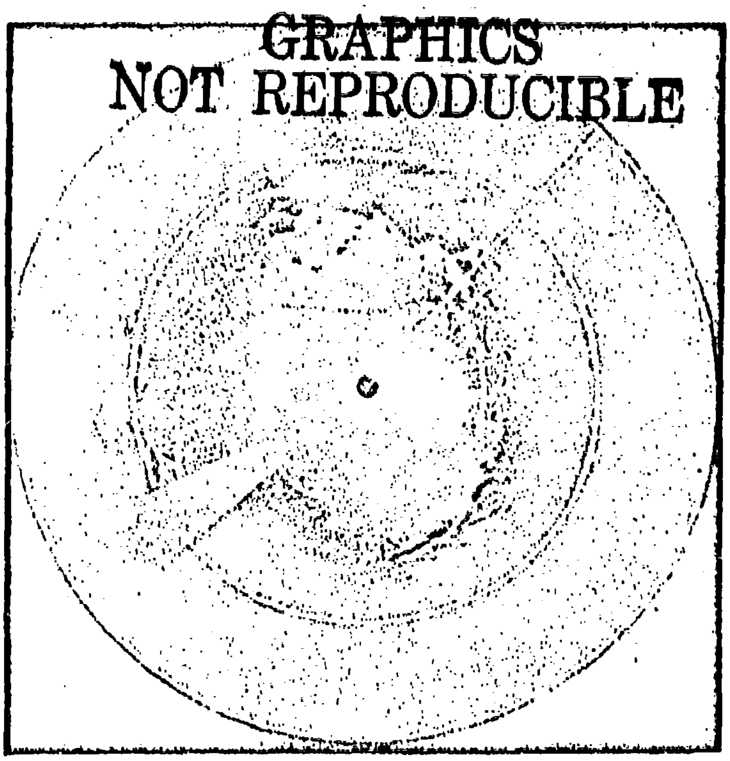

Figure 4.10. Mountains photographed from 39 m high. Distance between the circles: 9.25 km.

Earth targets can be recognized exceptionally well with the help of airplane radio location devices with lateral observation. These devices can observe earth targets without flying over front lines or national boundaries. The territory is observed by two antennae of which the directive patterns are extended on different sides of the airplane. The screen shows the picture of the pieces of land lying on both sides of the airplane route to a width of about 10 km. A signal for moveable targets is provided with the lateral picture radio location devices. This permits a clear picture of military equipment on the battlefield, troop concentrations, fortifications and other targets to be obtained. A side picture radio location station can also perceive objects with a very small reflection surface like airplanes, tanks, armored troop carriers, rocket launching ramps, etc. The radio location picture of the territory with an exact location of the targets will be transmitted from the airplane by radio to the control center where the electrically received signals will be transformed into very informative photographs of the photographed territory within a few seconds. The radio location picture of a lateral picture radio location device resembles territorial representation on a topographic map.

By comparing the radio location picture with the topographic map, the navigator of an airplane can orient himself and drop bombs by sight. Topographic maps which serve as a comparison with radio location maps are specially elaborated. All secondary details which cannot be ascertained with the radio location device nor visually are removed from the map. The radio location picture and the topographic map can be compared variously. One possible method is to place the topographic map, printed on transparent film, on the screen of the visual apparatus. For a more convenient comparison of the radio location picture and the topographic map, in the USA, e.g., a special device is used called a video converter (or picture transformer). The video converter is based on the photoelectric transformation of the territorial map into video signals. These are mixed with the video signals of the radio location device and then reach the signal. In this way the territorial map and the radio location picture of the territory appear on the video converter screen at the same time.

Dummy targets on the screen of a radio location device are not to be distinguished from true targets or only poorly. Therefore military objectives and targets can be masked from enemy observation with radio location devices. The radio location masking permits targets to be imitated in the shape of picture points on the sighting devices of the radio location apparatus, thus masking military equipment and objectives from radio location observation from air and ground (Figure 4.11) as well as changing the radio location picture of bodies of water and lakes (Figure 4.12) and simulating islands, dams and other objects. In this way use of radio location bomb sight devices can be made difficult for guided bombing and the opponent can be forced to use rockets, airplanes and ships against dummy targets.

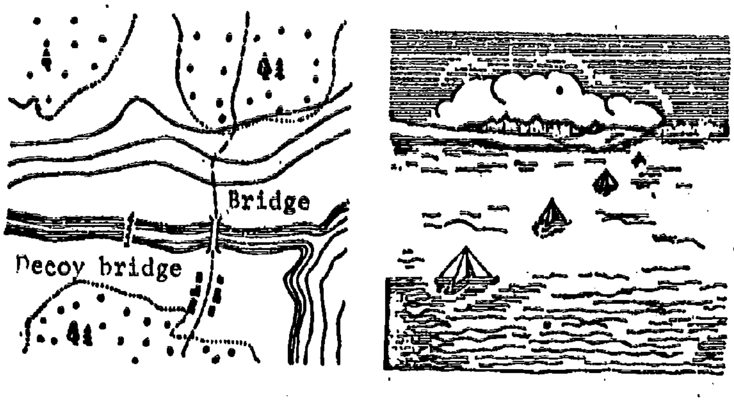

Figure 4.11. Establishment of a dummy bridge with angle reflectors.

The kind of radio location masking depends on the objects to be masked and on their discernability with radio location devices. For radio location masking are used radio location dummy targets which adapt the radio location pictures of the objectives to the radio location picture of the background surrounding it and hide technology behind natural features. Masking military equipment from ground radio location observation is done by clever exploitation of the masking qualities of the local relief and of the territorial objects lide hills, buildings, forests, etc. If the equipment is set under covers and in dead zones (imperceptible rooms), where reconnaissance with ground radio location media is excluded, they can be definitely removed from the radio location observation of the enemy. At the same time military equipment is thus protected against visual and infrared reconnaissance. In this respect a forest furnishes good cover. Leaves and needles among the trees produce a radio shadow which is analagous to light shadow.

The spaces imperceptible with radio location devices are determined from a map or diagram. Figure 4.13 shows one construction. Straight lines of sight are plotted from the possible installation points of hostile radio location apparatus to the possible covers (heights, forest, different territorial objects). Finally territorial sectors are set up for the lines of sight. Military equipment found in the imperceptible areas cannot be perceived by the ground radio location apparatus of the enemy. In addition to natural cover, artificially devised camoflauge of trees (Figure 4.14), twigs, metallic nets or angle reflectors can be used for radio location masking of military equipment against ground radio location apparatus. In this case the objects remain invisible to the radio location apparatus, because the artificial camouflage and the masked equipment produce one mark on the visual apparatus.

However, effective radio location masking will only be achieved if the targets and objectives are also masked against every other type of observation (visual, photographic and infrared reconnaisance)at the same time. If, for example, the reconnaise of the enemy is led astray with wooden dummies of military equipment (tanks, cannon, airplanes), these dummies should also be provided with radio location refectors, since they are to mislead not only visual and air reconnaisance, but also the radio location reconnaisance of the enemy. Thus total masking is to be formed in such a way that, if the enemy compares the reconnaisance results obtained from a sector of land with different means, no differences appear.

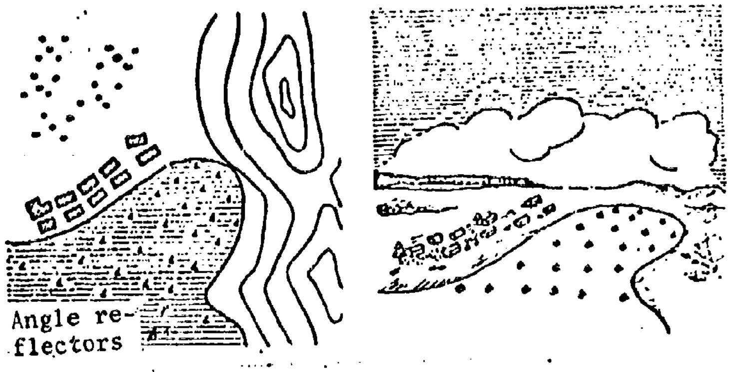

Figure 4.12. Masking part of a water surface against radio location observation from the air.

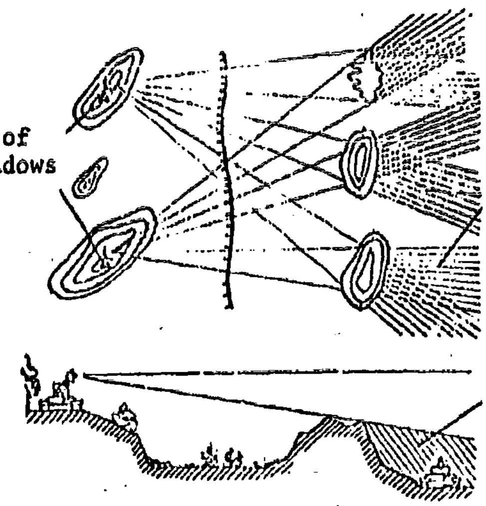

Figure 4.13. Construction of spaces not visible by radar.

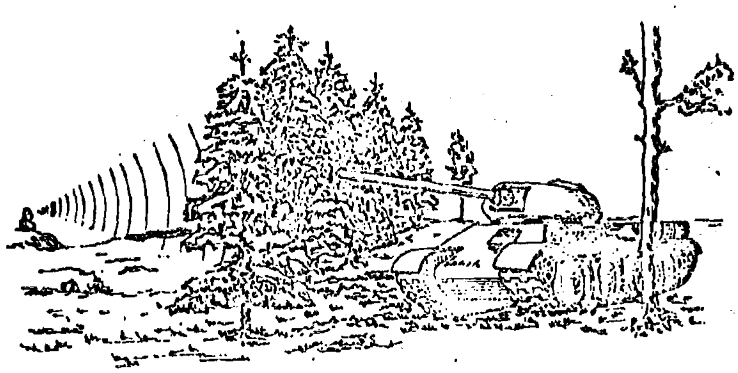

Figure 4.14. Natural cover.

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13. ABSTRACT

Military equipment and objectives can be masked from radio location observation through the use of special coatings. At the present time, two types of materials are used to diminish the intensity of reflection: absorption and interference materials. Absorption coatings must fulfill two requirements: they must not reflect electromagnetic waves and must absorb the waves originating in themselves. Rubber, polystyrol foam, coal dust and other porous materials are suitable for such coatings. The best types of surfaces for preventing reflection are waffle shaped and composed of sharp pyramids or cones. Mixtures of neoprene, carbon black, wool, iron filings and graphite are also suitable for damping wave reflection. Interference materials have a thickness equal to a quarter wave length or an odd numbered multiple of it so that waves are put out of phase and cancell each other. These were already used during the second war to protect German submarines. Lattice structures made of graphite pulver are used in this technology.

Infrared rays, given off by every warm body, can be picked up with special receivers. Smoke stacks and flues are particularly sensitive. Reducing temperatures and warming the surrounding atmosphere, for example

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absorption materials						
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with smoke, reduce infrared sensitivity. Heating other objects also makes it possible to set up dummy targets. Camouflage by radio location masking is used to conceal large objects, mobile or not. These are set up by using special angle reflectors to give the impression of waves from a real object, setting up special heat patterns, and plotting territory to find spots which are dead from the enemy's point of view in which to conceal large mobile objects. Comparison of reconnaisance results with topographic maps helps the enemy find hidden objectives. When camouflage is practiced, it should be done in such a way that all enemy reconnaisance results, whether visual, infrared, or radio locational, lead to the same results.