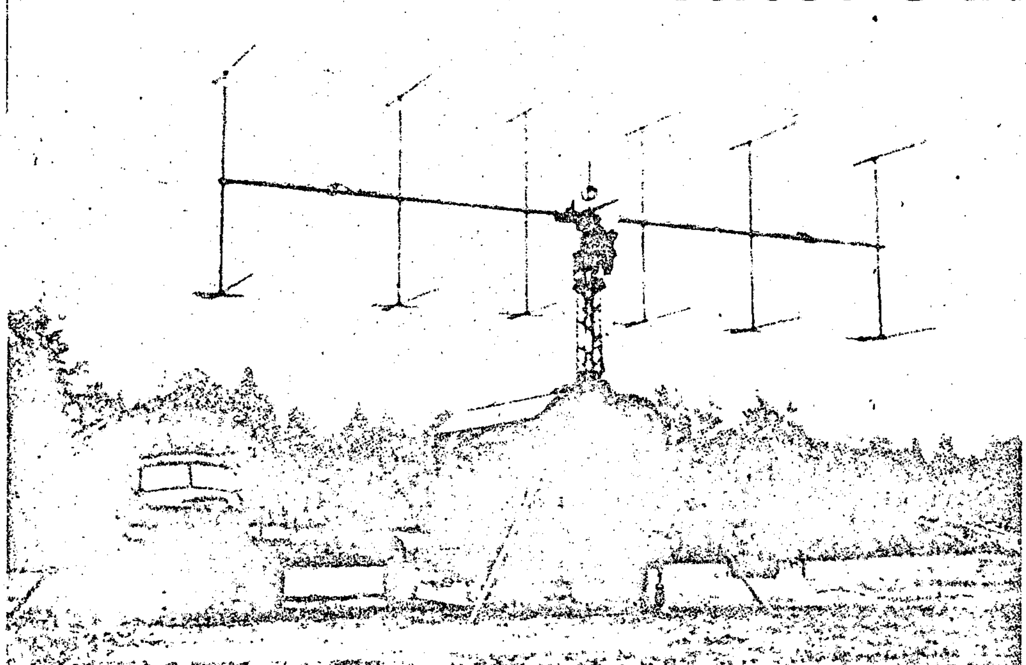
Radars visible on a Kashin-class guided missile destroyer include Owl Screech fire control radar (A) for twin 3.3-in. AAA turrets, Peel Group (B) tracking and guidance radars for SA-3 missiles, Head Net search antennas (C) and High Pole (D) IFF antennas.

Avionics

"Soviet Radars Disclose Clues to Doctrine"



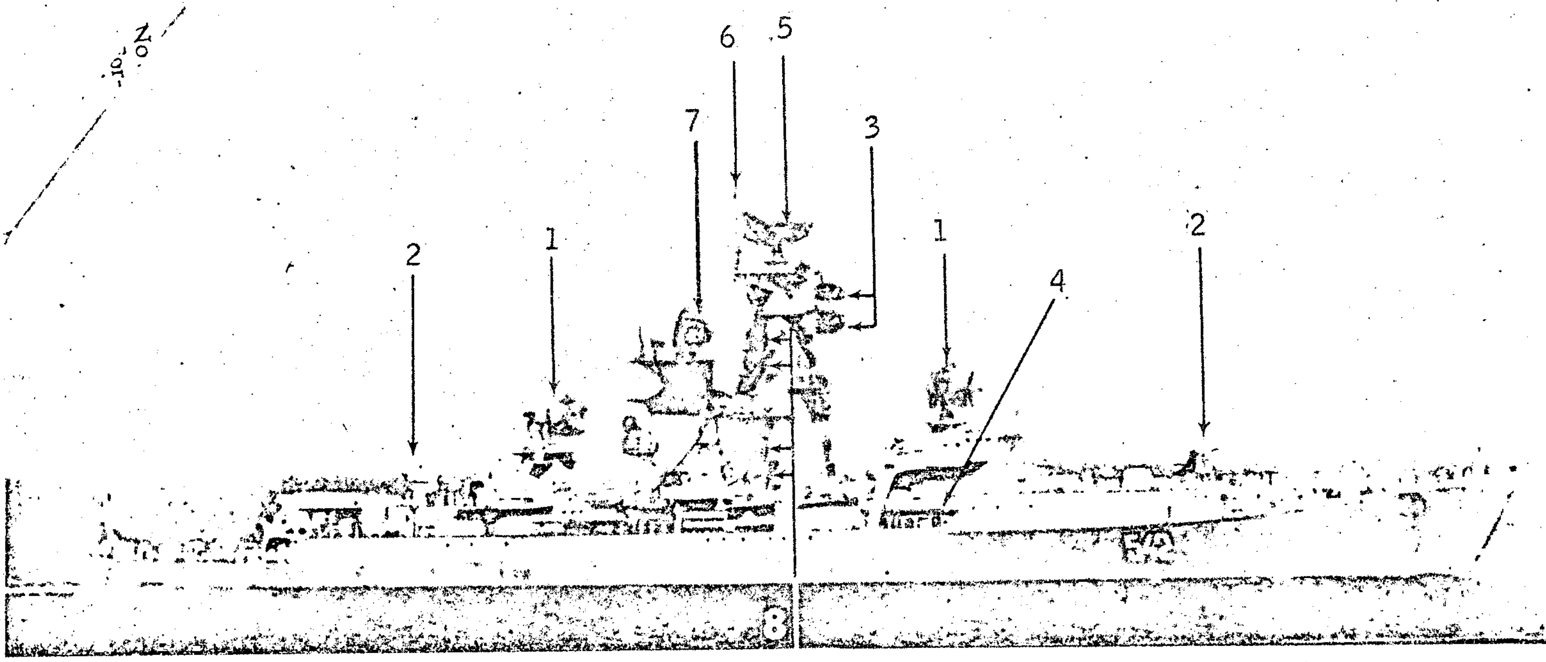
Soviet P-12 early warning search radar, also called Spoon Rest, operates at 147 to 161 mc. in the VHF range and at distances up to 150 naut. mi.

By Barry Miller

Analysis of Russian radar reveals a number of interesting clues about the Soviet Union's technology or otherwise reflects prevailing economic and military thinking in that country. The Russians are putting their radar technology on display daily within their own borders for photographic and electronic observation by American satellites and by aircraft near its boundaries. In Eastern Europe, the Middle East, Cuba and North Vietnam more direct observation is possible.

Much of the accumulated knowledge about this growing technology (AW&ST Feb. 15., p. 14) comes from advanced electronic listening and data gathering devices, but even more useful information has come by older, more obvious means. A few of the discernible threads in their radar technology include:

- **Mobility**—Most ground-based Russian radars (other than missile defense and space tracking) are van, truck or flat bed transportable and vans themselves



Kresta-class destroyer is outfitted with Peel Group radars (1) for target acquisition, tracking and guidance for SA-3 missiles (2). Scoop radar (3) is a fire-control sensor for the Shaddock surface-to-surface missile (4). Head Net surveillance antennas (5) are near High Pole IFF antenna (6). A search antenna (7) and what appear to be passive RF devices (8) also are visible.

are an integral part of the design. Even non truck-transportable U.S. radars given to the Russians were quickly converted for wheeled movement. In numerous cases vans are jacked up in the field and slowly rotated for circular scanning. The mobility of radar would simplify radar control of fluid battle lines and help insure air superiority in rapidly changing tactical environments.

■ **Quantities**—Large numbers of radars of all types employed by the Russians probably reflect Russian military doctrine molded by World War 2 experience that sees large masses of troops, armor, artillery and aircraft as essential for victory.

■ **Available Manpower**—Russian radar design presumes a plentiful supply of inexpensive manpower. This may account for the absence of emphasis on the sort of automaticity commonplace in U.S. equipment. The Russians, for example, have not stressed integrated displays as have the Americans. Thus, in some Fan Song radars, there are three separate display presentations, each manned by an operator, rather than a single combined display one man could manage. The Russians lack the economic incentive to use people efficiently since their obviously lower manpower costs are insignificant in any cost-effectiveness tradeoffs. With the abundance of manpower, the Russians are believed to have added to their Fan Song complement a man who serves as a visual observer for the purpose of helping the radar maintain track in a jamming environment.

■ **Lower Frequencies**—Russians concentrate heavily in lower frequency ranges such as VHF and UHF where many of their radars continue to operate despite, in the case of metric wavelength radar, poor accuracy and inability to detect low flying targets. This may reflect heavier work and greater familiarity with

Barlock early warning and ground control intercept radar has a pair of truncated paraboloid mesh reflectors with clipped corners. Entire van rotates for azimuth scan.

these wavelengths where their systems engineers might once have been compelled to work because of the absence of suitable microwave components. These radars do offer greater range for given amounts of power, do not have severe weather problems and do not have wind loading considerations of microwave antennas. Yet recently the Soviets have pushed into the high microwave ranges with notable success in high X band and K band.

Many of the lower frequency Russian radars, like Knife Rest A, B and C, Spoon Rest A, Dumbo and derivatives of U.S. Army Signal Corps-developed SCR-270 and SCR-271 do provide useful early warning or long range search functions, some to ranges of 100 naut. mi. or more.

The Israelis are believed to have captured one of these in late December, 1969, during a daring commando raid at Ras Ghareb, 125 mi. below Suez City. They seized and removed with Sikorsky CH-53 helicopters what was at the time described as a Russian-built P-12 radar, specially designed for use against low-flying targets. As late as September of last year, the Israeli army weekly Bamachaneh described the P-12 as, at the time of the raid, "one of the best and most sophisticated radars on Egyptian soil."

The Russian P-12 designation is for what NATO calls Spoon Rest A, a 147 to 161-mc. VHF band early warning radar housed in two trucks—one for the radar and erectable Yagi antenna and a second one for the generator. Spoon Rest A generates about 350 kw. peak power and can detect targets at about 150 naut. mi. ±1-2 mi. Its beamwidths of about 2.5 deg. in the vertical and more than 1 deg. in the horizontal plane do not suggest the low-flying target detection capability attributed to it by the Israelis. The Russians probably modified the set, possibly even adding a moving target indicator to boost its performance. More likely, observers theorize, the radar was located in an open advantageous spot, with a long, clear view of approach routes of attacking Israeli aircraft that made it particularly troublesome and difficult to jam. The incident led to the execution by the Egyptians of 14 of their men for gross negligence in permitting the radar's capture.

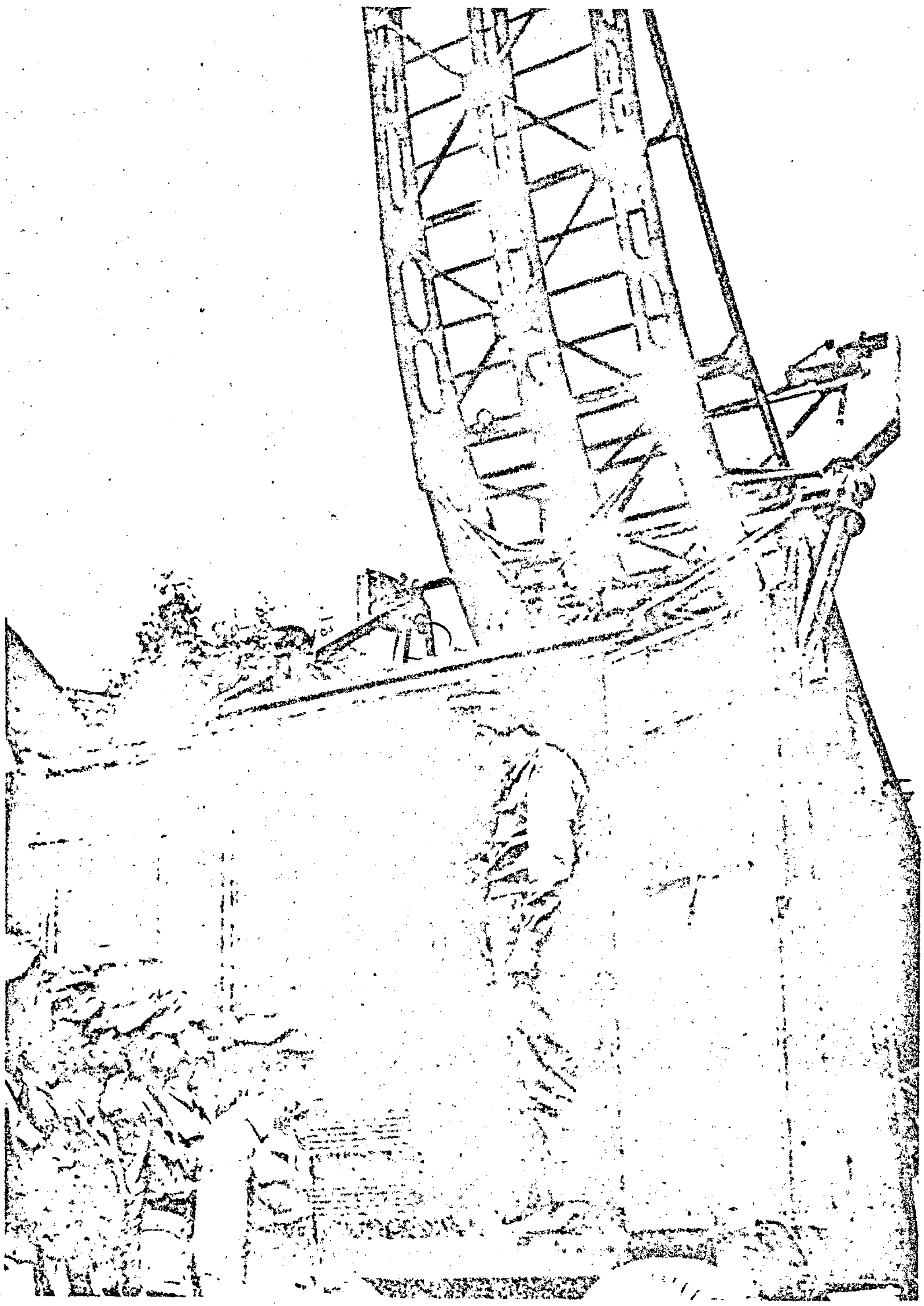
Among the booty seized by the Israelis during the six-day war was a badly-damaged truck-mounted Knife Rest radar (photo, AW&ST July 17, 1967, p. 84), from which Spoon Rest is derived, and an undamaged Fan Song B (AW&ST July 24, 1967, p. 61), a more advanced radar than Spoon Rest. The P-10 Knife Rest class operates at less than 100 mc., generates about 100 kw. peak power, has pulse widths of 4-12 microsec., a 25-deg. horizontal beamwidth and 21 deg. vertical. Range for Knife Rest A is 200 naut. mi.; for Knife Rest B and C it is about 50 naut. mi. In North Vietnam, the Russians deployed 34 Spoon Rest A sets, six 70-73 mc. Knife Rest A and 40 83-93 mc. Knife Rest B radars.

The VHF/UHF bands do offer attractions for ballistic missile defense applications. They can more readily detect low cross section re-entry bodies and impose on an adversary desirous of jamming defense radars the burden of using much longer lengths of chaff to match the longer wavelengths of defense radars.

■ **Multiple feeds**—Several types of Russian radars use multiple beams, possibly to increase total radiated power from the set, consistent with the customary Russian practice of using much high power. They have the additional benefits of yielding at least crude height-finding information and making the enemy's jamming task more difficult. The S-band Barlock ground control intercept and search radar is typical. A van-mounted mobile radar with two similar truncated paraboloid reflectors with clipped corners, Barlock has a range of about 175 naut. mi., ±0.05 naut. mi. and an azimuth angle accuracy of 0.5 min. Each of the two mesh reflectors is fed by three feeds, yielding a stack of six beams, each one supplying about 1 megawatt output. Frequencies are 2,695 to 2,715 mc., 2,715 to 2,750 mc., 2,815 to 2,835 mc., 2,900 to 2,990 mc., 2,990 to 3,025 mc., and 3,080 to 3,125 mc. The radar, designated P-50, has a PRF of 375 pps., pulse widths of about 1.8-3.1 microsec. for the S-band signals and 2.4 microsec. for an associated L-band IFF. Beamwidth is about 0.7 deg. The entire cab rotates for azimuth scanning at the rate of about 6 rpm. for early warning and twice that for GCI. Barlock was initially identified in 1959 and eight sets were detected in North Vietnam. Its predecessors, like Big Bar A, Big Mesh and Back Net, have similar six feed systems to perform the same functions. In Token, the Russians have a five-beam early warning/GCI system, like the American CPS-6B, operating in S band to yield a 140-180-naut. mi. range to within 0.5 naut. mi. accuracy for early warning and 100-200 mi. for GCI. In the latter case, accuracy of the van-mounted twin truncated parabolic mesh reflector radar is ±0.5 deg. in azimuth and 1,000 to 5,000 ft. in elevation.

■ **Arrays**—Antenna arrays are characteristic of much of Russian radar technology, ranging from simple dipole arrays at lower frequencies, to at least limited numbers of phased arrays. Usually, the arrays are mechanically scanned. The large radar antenna mounted atop the superstructure of the helicopter carrier Moskva, and called Top Sail, employs electronic scanning, possibly frequency scanning, in elevation, for long-range search and helicopter recov

■ **Heavy equipment**—Russian radars are heavy, despite the emphasis of mobility, in part because of the absence of advanced solid-state devices in much early equipment and the need to handle rela-



East European troops are instructed in operation of the truck-mounted Cake series of S-band height-finding radar, which is common throughout the Communist bloc. Nodding Cake series radars typically have 150 naut. mi. range and can locate targets to within about 1,500 ft. at 100 mi. Beams are roughly 3.5-4 deg. in the horizontal and 1.5 deg. in the vertical.

tively high power levels. At Ras Ghareb, a group of Israeli commandos having a combined lifting strength equivalent to the specified lifting capability of a CH-53 tried unsuccessfully to raise one of the two Spoon Rest vans to estimate whether the helicopter could remove the radar. Then the helicopter tried and succeeded in lifting the van in a display of greater than anticipated capacity.

▪ **ECM protection**—Many Russian radars have built-in protection against electronic countermeasures (ECM); others do not, suggesting that certain design groups were remiss in not anticipating the requirement or were victims of restricting priorities. Later model Fan Song and Low Blow radars evidence a major concern with an ECM threat. The Russians have corrected a serious design fault with some radar dummy loads that leaked energy when radars were operated into them to avoid acquisition by American aircraft. The leakage was sufficient to enable aircraft with homing receivers to home nonetheless on the radars.

The Russians, in turn, are adept at jamming, having acquired invaluable experience in the high frequency (HF) region by trying to block Voice of America and Radio Free Europe broadcasts. They have a remarkably good jamming control that permits noise jamming with proper power levels from the proper location for any special transmitter location and power level. Traditionally, the Russians are strong in electromagnetic theory and in HF radio propagation.

▪ **Limited Component Diversity**—Russian radar designs make maximum use of a limited number of components of different types and values, which simplifies field logistics. A small number of different magnetron types reappear in numerous radars. Their circuit design is more straightforward than their American counterparts. Their designers, according to reports, are very cautious, using much of what is already proven. Their radar designs are aimed at lower skill level maintenance and their mean-time-to-repair is believed to be shorter because of the design simplicity.

Russian SAM radars clearly reveal the influence of World War 2 German and American techniques. The Yo-Yo radar for the SA-1 missile system, currently deployed near Moscow, employs flapping scanning beams for target tracking, a technique believed to be inherited from captured German scientists who worked on the 25-ft. long, Nazi liquid-fueled Wasserfall anti-aircraft missile during World War 2. Yo-Yo uses six rotating antennas to cover a 70 x 70-deg. scanning area and can track simultaneously more than 30 targets. It is assisted by an acquisition radar called Gage.

The idea of using flapping beams over search sectors for tracking was introduced into the SA-2 Fan Song system, but in this case with an electro-mechanical scanning concept called the Lewis scanner, invented by Dr. Willard D. Lewis, president of Lehigh University, when he was a member of the technical staff of Bell Laboratories. A patent for the mechanism, issued to Lewis in 1954, was the primary source of unclassified information on the Lewis scanner for some time.

The scanner is a lens antenna used to produce a linear, sawtooth-like scanning motion of a fan-shaped radar beam through a restricted angle. Two scanners at right angles cover a reasonable angular volume of space. The combination of the fan-shaped beams and the audible chirping noise produced in the headset of a listener monitoring the output of a receiver's detector account for the NATO selection of Fan Song as a name for these radars.

The Lewis scanner is one of a category of virtual source devices that take a beam from a parallel plate region and with a reflector strip at 45 deg. to the aperture produce a virtual source for feeding a microwave lens. The straight line feed path is circularized by rolling the parallel plate region into a cylinder. Then rotating the feed at the base of the cylinder yields a virtual source that appears to be moving along a straight line. The continuous rotary motion of the feed horn provides high scan rates.

The rotary motion is converted by the geometry of the antenna into a sawtooth scan. The antenna beam scans through a sector linearly at a constant angular rate, then quickly snaps back and repeats the sweep. This sawtooth scan makes the device useful for track-while-scan radars, as the Russians are demonstrating. The Lewis scanner is a broadband device, limited perhaps at the higher frequencies by the vanishing separation between the parallel plates.

Although the U.S. military is not believed to use these electromechanical scanners for operational radar, Tasker Industries has built for the Air Force and Navy small quantities of radars with Lewis scanners in an attempt to duplicate electrically and physically Russian Fan Song radars (AW&ST Jan. 10, 1966, p.111). These have been placed on Strategic Air Command bomb scoring ranges to act as simulators or mimics of enemy emitters. Reeves Instrument Div. of Dynamics Corp. of America has built others for Tactical Air Command which are electrical mimics; Guide Industries, Inc., Sun Valley, Calif., is working on other models. Tasker also is developing a Low Blow mimic while Data Design Laboratories is building transportable radar and countermeasures simulators of Russian ship-based radars for the Navy.

There are indications that in the continuing modifications and improvements the Russians are building into their Fan Song radars and the parallel efforts by U.S. contractors to mimic Russian progress for training purposes, each side at times has squeezed from these scanners better performance than the other and each side may have learned from the other's advances.

As the Lewis scanner radars are mechanized by the Russians, there are two scanners at right angles to one another, roughly in a backward letter "L" configuration mounted on a truck-drawn van. Each of the trough-shaped scanners generates a fan beam, narrow in the plane of the scan. In the S-band Fan Song A and B, the beam is roughly 2 deg. in the narrow dimension, 10 or more deg. in the other. The C-band versions are about 1.5 x 7.5 deg.

The fan beam in the vertical trough then sweeps up and down; the one in the horizontal scanner from side to side, thereby covering a solid angle of space. The two beams are slightly offset in frequency from one another with one typically, at about 2,965 mc. to 2,990 mc., the other at 3,025 to 3,050 mc. Rotating the van changes the azimuth sector to be scanned, while the entire structure may tilt in elevation. Peak power output for the S-band version is about 600 kw. and the radar's unambiguous range is 32-64 naut. mi. The Fan Song B has a small

Air Force recently began negotiating with three finalists in its competition for a radar warning receiver system for the McDonnell Douglas F-15 air-superiority fighter. The three are Applied Technology Div. of Itek, Loral and Sylvania Electric. The system (AW&ST Feb. 1, p. 11) will alert an F-15 pilot to airborne and ground-based radar threats. A decision from among the three is expected momentarily.

Flight test bid for the B-1 military avionics system which USAF is considering for the new North American Rockwell strategic bomber (AW&ST Feb. 15, p. 47) probably will be a large transport, possibly a Lockheed C-141 or Boeing C-135 transport.

Several studies of an autonomous navigation system for military spacecraft are planned by USAF's Space and Missile Systems Organization. The studies will try to identify suitable light weight and low power navigation sensors, orbit parameters that need to be computed in real time and the best ways of performing navigation equations. Hardware currently being developed for the space precision attitude reference system, essentially an attitude and pointing system, may find applicability later in the navigation program.

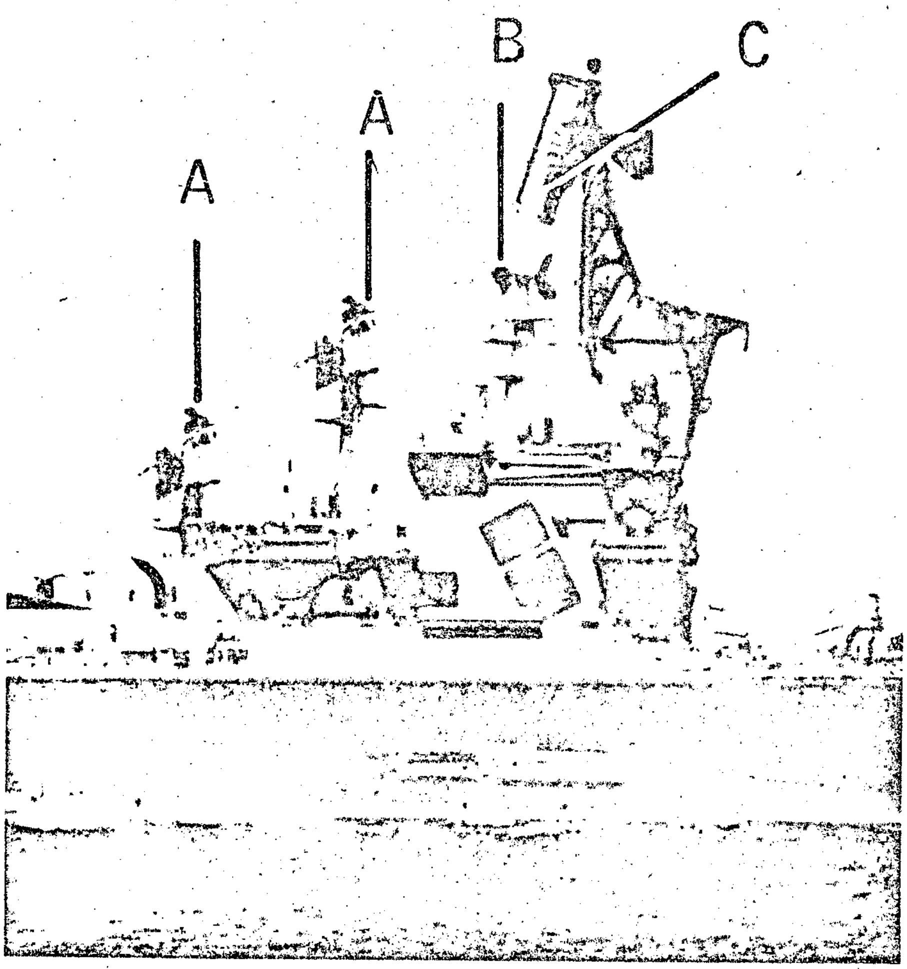
Feasibility of using a tethered, possibly balloon-borne emergency transmitting antenna for Loran D ground transmissions is to be explored in a forthcoming Rome Air Development Center activity. Meanwhile, Air Force may finally be on the verge of starting a series of Loran receiver developments slated for several types of military aircraft (AW&ST July 13, 1970, p. 55) originally planned for last year. The Coast Guard also is evaluating proposals for low-cost Loran receivers and Transportation Dept. is investigating a possible Loran automatic vehicle monitoring concept.

Light, not lather, is sought from the "soap" being investigated by Westinghouse Electric Corp. for USAF Avionics Laboratory. An acronym for silicate-oxy-apatite, this soap is being studied for its potential as a host material that would enable a Q-switched neodymium laser to provide higher energy per pulse than yttrium-aluminum-garnet (YAG) and operate at a higher efficiency than glass. Apatites are calcium phosphate minerals.

Digital data transmission rates as high as 600 megabits/sec. have been demonstrated with a laser communications link developed by Lockheed Missiles & Space Co. Quadriphase shift keying is used to modulate the laser beam optically. Lockheed has previously reported transmissions at a 300-megabit per second rate (AW&ST Feb. 15, p. 47).

Corning Glass Works has begun selective sampling of its new family of glass-ceramic material that can be machined to precision tolerances with conventional metalworking tools. The material exhibits a broad range of dielectric and mechanical properties suitable for electrical, electronic and aerospace applications, according to Corning. Properties include an insensitivity to surface damage and high resistance to the normal effects of such damage on strength, typically seen in conventional ceramics and glasses.

Semiconductor structure that will enable a 40% reduction in the size of bipolar digital microcircuits has been developed by Fairchild Camera & Instrument Corp. The structure employs an oxide, rather than a conventional diffusion process to electrically isolate each transistor in a circuit from its neighbors. The new process, called Isoplanar, is expected to enable bipolar circuits to achieve the packing densities of current metal-oxide-semiconductor (MOS) circuits. Isoplanar structures are said to be less sensitive to masking and photo-etching defects, enabling higher yields and lower costs along with the higher packing densities.



Soviet helicopter carrier Moskva has twin missile tracking and control groups (A) for use with SA-3 missiles. Heat Net search antennas (B) and large multiple-element surveillance radar (C) that uses electronic or frequency elevation scanning also are visible.

parabolic dish, mounted at the end of the horizontal scanner, for sending UHF guidance pulses to the missile.

Later C-band Fan Song radars, like Fan Song E, have an additional pair of parabolic dishes, one horizontally and the other vertically polarized, located on top of the horizontal scanner. These provide a lobe-on-receive-only (LORO) mode, also an integral part of SA-3 Low Blow, that counters an adversary's use of deception electronic countermeasures (DECM). Normally, a target aircraft equipped with proper warning receivers can tell which portion of the beam radiated by the trough scanners is illuminating it, thereby knowing whether the radar is locked on. To confuse the radar, it can use DECM techniques, essentially shifting the apparent target angle. With LORO, the troughs stop radiating and operate into a dummy load. The small dishes with wide beams radiate and the troughs receive the returns, thus denying the target the opportunity of determining where in the beam it is situated, hence whether it is the intended SAM victim.

The C-band Fan Songs are offset by a slightly greater frequency than their S-band counterparts: 4,910 to 4,990 mc. for one scanner, 5,010 to 5,090 mc. for the other. Peak output power is more than double at 1.5 megawatts, while unambiguous range is 40 to 80 naut. mi. Pulse widths are 0.4 to 1.2 and 0.2 to 0.9 microsec. Search PRF is 900 to 1,020 while track PRF is roughly double that figure at 1,740 to 2,070 pps.

Fan Song radars can track simultaneously about six targets and guide three missiles against hostile aircraft simultaneously. One of the main shortcomings is that Guideline missiles must pass through the guidance beam within 6 sec. after launch or else the missile will not be acquired for direction to the target. This would account for frequent pilot observations of missiles fired on apparently aimless trajectories. Also the missile's ability to get only three levels of steering information from the ground circumscribes its accuracy.

Low Blow also uses a pair of electromechanical scanning trough antennas, but in this case to reduce ground clutter expected during tracking at low altitudes or low grazing angles the troughs are 45-deg. angles with respect to the ground but at right angles to one another. The two scanners and the ground form an isosceles triangle with the ground as the base of the triangle. At the center of the triangular configuration is a LORO parabolic transmitting dish (at least in Egyptian versions) that goes into operation immediately after target acquisition. Above the apex of the triangular configuration is the L-band parabolic guidance command dish.

While the trough scanners generate sawtooth, flapping fan beams, they are not Lewis scanners. Rather, they are speculated to be an NRL (Naval Research Laboratory) organ-pipe scanner in which a small, rotary driven feed horn propagates successively through equal lengths of waveguide originating around the circumference of a circle, like railroad tracks at a roundhouse, with the horn as the rotating arm at the center. The waveguide channels terminate in parallel as a linear scanner aperture to form a straight line scanning aperture. The energy then radiates linearly one by one across these channels.

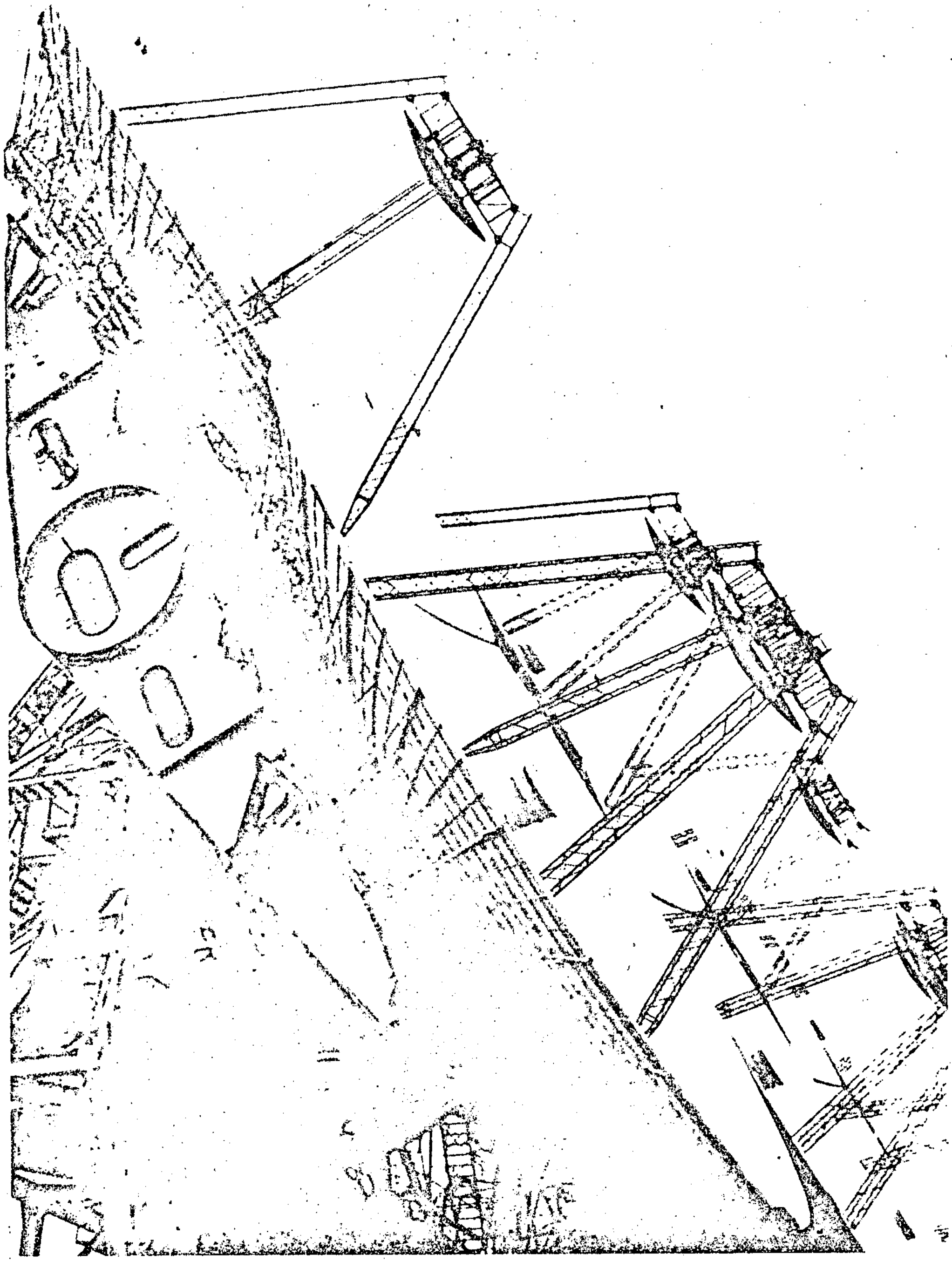
Low Blow operates at 9,000 to 9,400 mc. in X band with a PRF of 1,750 to 3,500 pps. and pulses of 0.25 to 0.5 microsec. in duration. Power output is about 250 kw. There is an 8:1 sector beamwidth over a 12-deg. sector. Antenna gain is about 40 db. Unambiguous radar range is 24 to 48 mi., depending on PRF.

There is speculation that Low Blow and with it the SAM-3 system is not operating satisfactorily.

In operational deployments, Low Blow is supported by a truck-mounted acquisition radar, the P-15 Flat Face, with its two elliptical paraboloid reflectors, each about 37 x 18 ft. This 400-kw. UHF radar has 160 mi. range ±100 yd. and 0.5 deg. in angular accuracy. It operates at about 810 to 850 mc. and 880 to 905 mc. with two PRFs—200 to 800 pps. and 600 to 680 pps. Elevation beamwidth is approximately 5 deg. and about 10 deg. in azimuth. Another radar, Squint Eye, offers better low altitude coverage in support of Low Blow. About 40 Flat Faces are in North Vietnam.

Spoon Rest performs an analogous acquisition function for Fan Song A and B with Long Track, still another search radar, also serving an acquisition function.

Russians as well as the Poles and Communist Chinese have large numbers of S-band height finders, many of them with the NATO suffix "cake," like Patty Cake, Rock Cake, Stone Cake, Sponge Cake as well as Side Net, the Polish Nysa B and Chinese Rice Cup. Typically, these are large nodding peel-shaped mesh parabolic reflectors generating beams of roughly 3.5 deg. in the horizontal plane and 1.5 deg. vertically. They nod at about a 30 to 40-per min. rate, scan through limited azimuth angles and have ranges



Soviet preference for arrays is indicated in this bank of eight large parabolic reflectors ganged together to increase effective aperture and radiate narrower S-band beams for space tracking. Each reflector has a Cassegrain feed with a smaller hyperboloidal dish supported by a quadripod structure at the apex and feed at dish center. Array can tilt in elevation and is rotatable in azimuth.

upwards of 100 naut. mi. Sponge Cake for example has a 160 to 190 naut. mi. range ±1 naut. mi., and ±1,500 ft. at 100 naut. mi. Antenna gain is about 36 db.

Large quantities of ground-based IFF systems such as the Witch series, Score Board A & B, Foil Two and Rod Mat have been identified.

Russian warships, especially their Kresta, Kynda and Kashin classes of guided missile armed destroyers (AW&ST Dec. 9, 1968, p. 61) reflect a heavy naval shift toward radar controlled short-range surface-to-air Goa missiles (with X-band Peel Group tracking and guidance and Plinth Net acquisition) and surface-to-surface Shaddock missiles (with Scoop Pair fire control). A number of these ships have S-band paraboloidal azimuth search reflectors, some back-to-back like Head Net, presumably to double the data rate and resolution especially useful in high sea states. Other search radar antennas include Slim Net, Sea Net, Hair Net, Sheet Bend, Sheet Curve, Strut Curve and Knife Rest.

None of the sleek missile destroyers carry the high altitude Guideline missiles, probably because of the inability at the time they were built to satisfy the difficult demands of the Lewis scanners for stabilization on a rolling platform.

This would explain the later introduction of the SA-N-2 (naval Guideline) on the Dzerzhinski, a bigger ship where stabilization would be easier. It is unclear what kind of multiple target capability Peel Group has for the SA-N-1 (Goa). Its only difference from Low Blow is that guidance signals, presumably transmitted through the two smaller peels among the group, are in the 3 to 4-gc. range.

Peel Group's four orange-peel antennas are asymmetrically situated in what from the front is a "rectangular" pattern on a large mount that is rotatable in azimuth. Each antenna appears to be of a different size. One large peel is in a vertical position on a separate horizontal shaft from the main mount so it can be scanned in elevation. A separate larger peel, in a horizontal position at the bottom of the "rectangle," scans in azimuth. The two smaller dishes, one vertical, the other horizontal, occupy the top and left side positions of the "rectangle."

There are reports the Russians may use a TV tracker to aid the shipborne SA-3, much as they rely on visual or optical aids to assist radar tracking and AAA sighting. The use of optical tracking devices could account for the present American drive to develop electro-optical countermeasures.

Increasingly, Russian ships are coming to resemble American warships with radar antennas cluttering their otherwise clean lines. Consequently, some observers speculate, wishfully, perhaps, that the Russians may stumble over the same thorny electromagnetic interference problems the U.S. Navy did when it began to increase rapidly the number of radar emitters on its ships.

Russian submarines are outfitted with surveillance radars, like Boat Sail, that closely approximate in operating frequency, pulse width and PRF the typical American naval surface radars. This probably reflects a Russian choice for optimized performance in a sea clutter environment but it conveniently gives the Russians the ability to surface at night amidst American task forces and conduct radar surveillance without fear of their signals betraying them to American elint receivers. The submarines also are equipped with Stop Light and Watch Dog broadband receivers for passive surveillance.

Other naval radars include Square Tie, the Styx cruise missile acquisition radar on Osa class missile boats; Drum Tilt fire control radar for 37-mm. AAA on torpedo boats; Pot Head and Pot Drum surface search and torpedo fire control, and Snoop Slab surface search on E-2 and J class submarines.

(This is the concluding article in a series on Soviet radar. The first appeared in AVIATION WEEK & SPACE TECHNOLOGY, *Feb. 15, p. 14.)*

Check ordered