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5. CRITERIA FOR SITE SELECTION AND FREQUENCY ALLOCATION
(Keynote Paper)

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INTRODUCTION

During the first Workshop on Technical Aspects of MST Radar two recommendations were adopted on site and frequency selection, which first shall be repeated here; then we will make suggestions as to how to implement the recommendations, as well as summarize existing results, criteria and experiences to support the design of planned radars. Since the criteria to operate a radar will be quite different according to individual requirements of research groups, only summaries of items will be considered without aiming too strongly at their individual assessments.

(a) Recommendation on Site Selection

Although the actual interference problem will not be known until the antenna and receiver are installed, the prudent experimenter will conduct tests of interference before selecting a site. For large and expensive facilities these tests should be extensive and sensitive. A small directional antenna may be suitable to simulate sidelobe sensitivity of radars, but it should be remembered that sophisticated data-processing methods make system sensitivity extremely good; therefore it would be advisable to use (if possible) the complete data system to look for interference. These measures would certainly be called for before installing expensive, fixed sites.

(b) Recommendation on Frequency Selection

There is the difficulty of allocation of frequencies -- almost continuous use by these radars will be made when the band 40-60 MHz is allocated to other services. It was agreed that URSI should be contacted to see if they can make overtures to CCIR concerning this question.

More attention should be paid to the problem of designing MST radar antenna with lower sidelobes which will help both transmitting and receiving. This will help in the problem of MST radars interfering with each other in future.

SITE SELECTION

For selecting a location of an MST radar, one basically has to consider two general criteria, namely (a) the geophysical/meteorological phenomena which shall be investigated and (b) the operational requirements and capabilities one needs and which limitations one is able to accept.

Directions of priority of research could be towards synoptic scales (time scale of days), mesoscale (hours) or microscale (minutes). Microscale disturbances in the atmosphere are partly connected to orographic features (mountains,

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islands) and can influence considerably the accuracy and evidence of investigations of synoptic and mesoscale features. The latter are also influenced by the orography. Decision consequently has to be made to set up a radar in a mountainous or in a plain area. Of course also global climatology, i.e. research directed towards tropical, midlatitude or arctic atmosphere, will influence the selection of the radar location.

Some criteria to select a site, placing priority on optimum operation:

(1) Size of area (sufficient for antenna and equipment).
(2) Flatness and horizontal levelling, (antenna pattern accuracy).
(3) Vegetation, e.g. grass, bushes (influence maintenance of antenna).
(4) Composition of ground, e.g. rocks, soft soil, swamp, ... (influence antenna construction and reliability).
(5) Cultivated or wasteland (influences costs),
(6) Cattle or wild animals (may destruct system),
(7) Shielding by hills (avoid clutter and attenuate interference).
(8) Vicinity of next house or village (interference, security, service).
(9) Vicinity to institute or laboratory (travel, trouble shooting, maintenance).
(10) Electric power line (distance, costs to connect the system).
(11) Stability of line voltage, (reliability of operation).
(12) Water supply.
(13) Road access.
(14) Availability and cost of telephone line, (voice and data transmition).
(15) Noise interference from power line, close-by factories, roads (ignition noise).
(16) Height above sea level (pick-up of long distance groundwave interference, higher altitude permits increase of upper height to be sounded by radar).
(17) Distance from country border line (unexpected future radio interference).
(18) Costs to prepare the site and to rent and to maintain the site (duration?).
(19) Snow cover (antenna reliability and road access).
(20) Windbreaks (antenna construction).
(21) Probability of flooding.
(22) Aircraft flight routes (clutter and interference).
(23) Other close-by radio/radar systems (mutual interference).

These items may not be exhaustive but can give a guideline and were discussed and completed during the workshop discussions. The weighting of these different items has to depend on individual orientations and requirements.

A short discussion shall be added to item 7 on the clutter problem (i.e., signal returns from unwanted targets). In another paper (Paper 5.1-B, this volume) this author concludes that a shallow valley may be sufficient for shielding, even a flat plain may be acceptable, if no extraordinary conditions (e.g., very high extending mountains, buildings or radio towers in the surroundings up to several 10 km) spoil the atmospheric signal. Also seaclutter can be avoided by these means. Clutter from field-aligned ionospheric irregularities, however, can occur at locations close to the magnetic equator at near zenith angles (through the antenna main lobe) and at high latitudes at low elevation angles (through low angle sidelobes).

FREQUENCY SELECTION AND ALLOCATION

Following the early operation of the Jicamarca Radar which proved its applicability for probing the mesosphere, stratosphere and troposphere, the following generation of radars operated in the same frequency band between 40 MHz and 55 MHz (Figure 1). Although it proved true that very efficient radar investigations of the lower and middle atmosphere can be done using these frequencies (which in the early times was strongly questioned by traditional radar meteorologists), it is not yet established that this frequency band is the optimum. Lower frequencies obviously may suffer from interference due to ionospheric propagation and a strong increase in sky noise (about inversely proportional to the square of frequency), but will allow larger antenna areas (increase of echo signal strength) and may yield stronger contributions from partial reflection. On higher frequencies the noise level decreases, improving the sensitivity and thus may allow operating with lower transmitter power and antenna gain. However, the wave number spectrum of atmospheric reflectivity is not yet known sufficiently accurately to permit a final decision which frequency may be optimum. An upper limit is obviously given by the high frequency boundary of the inertial subrange of atmospheric turbulence, determining the maximum height to be sounded. Mesospheric turbulence scatter, for instance, cannot be detected at much higher frequencies than 50 MHz, and at 430 MHz the upper height is even as low as about 30 km. It is evidently noticed also (Table 1) that all higher frequency radars (430/440 MHz, 930 MHz or 1290 MHz) use considerably higher power, although the reason is that these radars are operated mainly for incoherent scatter observations of the ionosphere. We will concentrate here on the frequency selection and allocation in the standard frequency band of MST radars in the low VHF range.

During the last World Administrative Radio Conference in 1979, worldwide frequency allocations were newly arranged and accepted. In Table 2 we have summarized the allocations between 30 MHz and 68 MHz, which are subdivided according to the worldwide Regions I, II and III (Standard of the ITU-International Telecommunications Union, see Figure 2). Except for three fairly narrow bands 30.005-30.010 MHz, 37.5-38.25 MHz, 40.66-40.70 MHz, no special allocations are furnished for scientific research purposes on an international basis. The used VHF radar frequency bands are merely allocated through national authorities, and it is evident that no legal claim can be brought forward by radar researchers to obtain a frequency allocation. The radars are permitted only to operate on the noninterference basis; i.e. they have to cease operation if interference to the primary or secondary services operating in the same band is reported. The services which most likely can be affected are the fixed and mobile (example in Table 3a), the amateur (Table 3b) and the TV broadcast service (Table 2). Fortunately, no major complaints by these services are known which would prevent VHF radar operation or even yield to decisions of national authorities to refuse issuing new licenses.

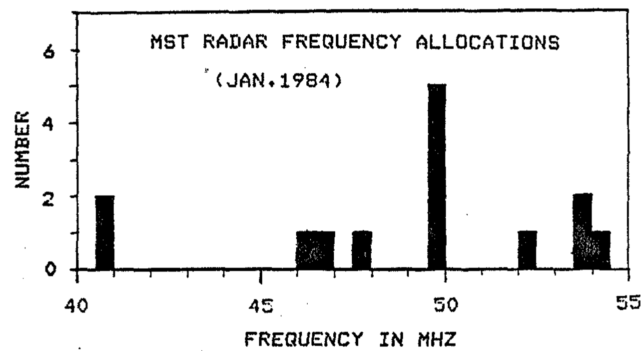

Figure 1.

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Table 1. Operational and planned MST/ST/IS radars (Nov. 1983). From ROTTGER (1984).

facility	mode	lat./long. deg.	freq. MHz	ave.power kW	min.pulse width μs	duty cycle (max.)%	antenna					status	ref.
							aperture (eff.) m^2	beam width	configuration	mode	steerability		
Arecibo/Puerto Rico	IS, ST	19N,67W	430	120	1	6	50000	0.17°	circ.dish	DB	20°(m)	op	(1)
" / "	MST		46.8	1	1	2	50000	1.7°	"	DB	"	cs	
Buckland Park/Australia	(M)ST	35S,138E	54.1	0.4	7	0.7	7500	3.2°	PAC,PAY	DB,SA	15°(1)	(op)	(2)
Chung-Li/Taiwan	(M)ST	25N,121E	52	4	1	2	2500	5°	PAY	DB,SA	15°(2)	cs	(3)
EISCAT/	IS,ST	70N (67N)	933.5	250	2	12.5	520	0.6°	3 circ.dishes	DB	80°(m),tristat.	op	(4a)
North Scandinavia	IS,ST	19E (27E)	224	600	2	12.5	3300	0.6°,1.7°	cyl.dish	DB	30°,60°,20°(m)	cs	(4b)
Equatorial Pacific	ST (3×)	(0,150E)	49.8	0.2	5	(2)	(5000)	(5°)	PAC	DB	15°(2)	pl/cs	(5)
India	MST	—	45-55	60	1	2.5	20000	3°	PAC	DB	20°(2)	pl	(6)
Jicamarca/Peru	MST,IS	12S,72W	49.9	200	(1)	5	80000	1.06	PAC	DB,SA	3°(m)	op	(7)
LSEET/France	ST	43N,5E	47.8	1	2	1.7	3×2000	5°	PAC	DB	15°(2)	cs	(8)
Millstone Hill/USA	IS,ST	43N,72W	440	30	2	1.6	1640	1°	circ.dish	DB	<80°(m)	op	(9)
MU/Japan	MST,(IS)	35N,136E	46.5	50	1	5	8330	3.6°	PAY	DB,SA	30°(m)	(op)	(10)
Penn.State/USA	ST (3×)	41N,78W	48-50	1	4	2	2500	5°	PAC	DB	15°(2)	pl	(11)
Platteville/USA	ST (4×)	40N,105W	49.8	1	4	1.7	2000	5°	PAC	DB	15°(2)	op/rt	(12)
Poker Flat/USA	MST	65N,147W	49.9	128	2	2	40000	1.4°	PAC	DB	15°(2)	op/rt	(13)
PROUST/France	ST	45N,2E	935	(~10)	4 (0.2)		2000 (95)		2 dishes	DB	bistatic	(pl)	(14)
Sondre Stromfjord/Greenland	IS,ST	67N,51W	1290	100	(1)	3	420	0.5°	circ.dish	DB	90°(m)	op	(15)
SOUSY/Germany	MST	52N,10E	53.5	24	1	4	3200	5°	PAY	DB,SA	12.5°(m)	op	(16a)
" /Norway	MST	69N,16E	53.5	8	1	4	8800	3°	PAY	DB	4.0°(2),5.6°	op	(16b)
Sunset/USA	ST	40N,106W	40.5	16	1	2.5 (16)	2200	4.4°,4.8°	PAC	DB	60°(2,m)	op	(17)
United Kingdom	MST	—	~50	12	1	5	5200	3.6°	PAY	DB	5°,10°(2)	pl	(18)
Urbana/USA	MST	40N,88W	40.9	6	10	1	2000	(<3°)	PAD	DB	1.5°(1),2.5°(2)	op	(19)

mode: IS = incoherent scatter (thermosphere, may include mesosphere)
MST = mesosphere,stratosphere,troposphere
ST = stratosphere,troposphere

antenna:
configuration: PA = phased array
PAC = phased array, coaxial-collinear dipoles
PAD = phased array, dipoles
PAY = phased array, Yagis

mode: DB = Doppler beam swinging
SA = spaced antenna (interferometer)

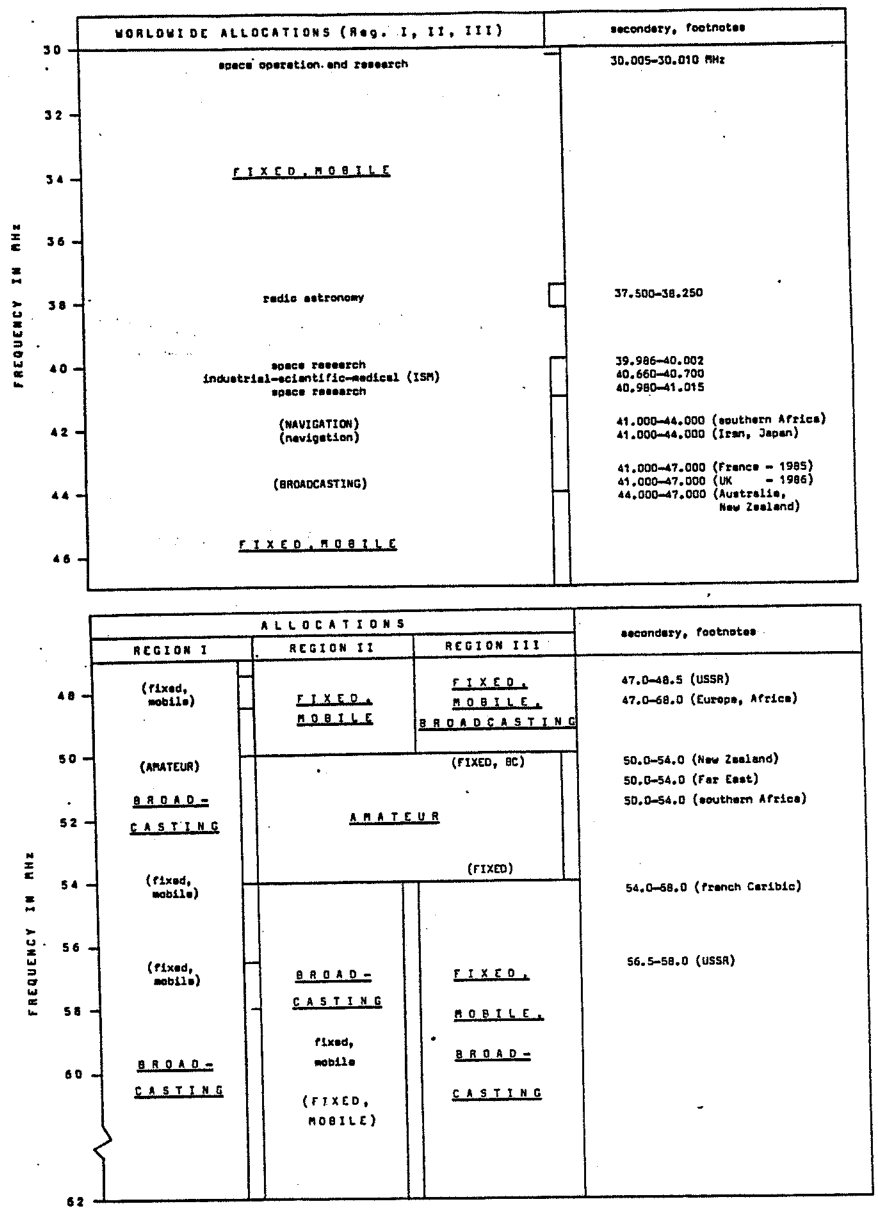
steerability: 15°(2) = zenith angle 15° in 2 orthogonal planes (and zenith)
15°(m) = multiple position out to 15° zenith angle (and zenith)

status: op = operational
op/rt = routine operation (continuous)
cs = under construction
pl = planned

ref.: (1) Woodman+); (2) Vincent et al., 1982; (3) Broanahan et al.+); (4a) Röttger et al.+); (4b) Hagfors et al., 1982; (5) Balsley+); (6) Koshy+); (7) Woodman and Guillén, 1974, Woodman and Farley+); (8) Crochet+); (9) Rastogi+); (10) Kato+); (11) Peters+); (12) Strauch et al., 1983, Strauch+); (13) Balsley et al., 1980, Balsley et al.+); (14) Glass+); (15) Watkins+); (16a) Röttger et al., 1978; (16b) Czechowsky et al.+); (17) Green et al., 1975, Green+); (18) Hall+); (19) Røyrvik and Goss+)

+) = in: Bowhill (1984), Handbook for MAP 9.

Table 2. Worldwide frequency allocation plan (ITU). Capital letters denote primary services.



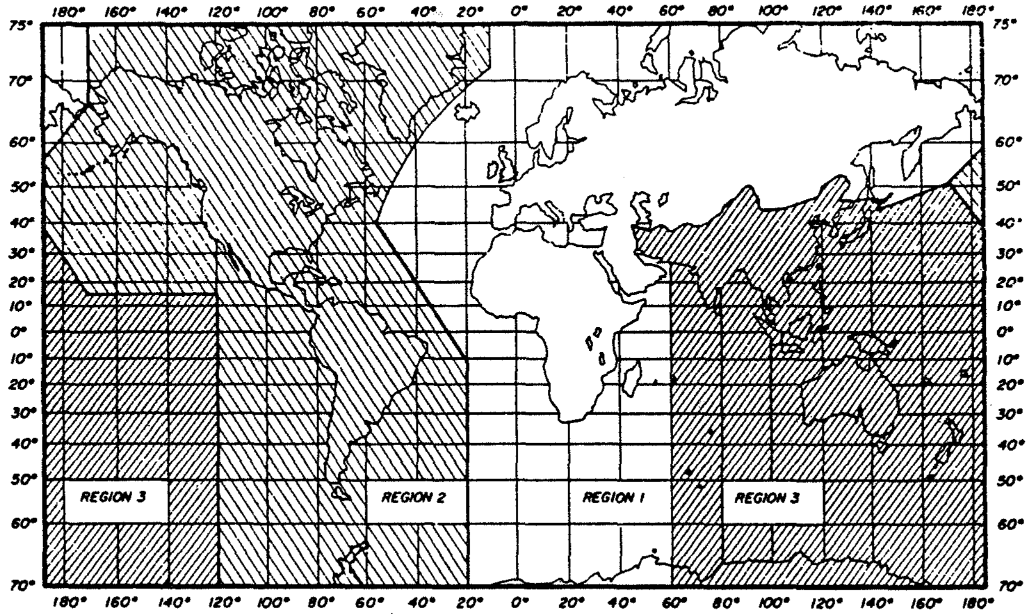


Figure 2. ITU-Regions.

Because of the fact that the VHF radars mostly cover a fairly wide bandwidth (100 kHz-2 MHz), the transmitted energy is spread out into a fairly wide frequency band, which yields less interference to narrow band operations such as those of the fixed, mobile or amateur services. Furthermore, interference is strongly suppressed because the main beam direction of VHF radars is vertical. Only a minor fraction of the energy is transmitted horizontally through the sidelobes where it could cause harmful interference to the other services. More observation has to be pointed to the fact that the radar reception will be disturbed by transmission of other services.

This problem, however, is mostly not too crucial if provision is made that the operations are properly separated in space and frequency. Since essentially ground wave propagation occurs, the field strength of interfering signals will be negligible at distances of several 10 km. However, in the lower VHF range ionospheric propagation can still occur and drastically increase the interference level. This is shown in the example of Figure 3, where the diurnal variation of frequency occupation monitored in December 1979 and January 1980 at the Arecibo Observatory is shown (after ROTTGER, 1980). Signals observed in the morning hours (06-12 AST) evidently originated through ionospheric propagation from the US mainland. The cumulative distributions of Figure 4 indicates occurrence maxima at two channels around 43 MHz and 49.5 MHz which were due to local traffic. The best choice of frequency was 46.8 MHz. It is strongly suggested to carry out similar frequency surveys before applying for a license to operate a VHF radar.

We see from Table 2 that the band 47 (54)-58 MHz is mostly covered by TV broadcast allocations (TV-band I), although partially also the fixed or mobile and the amateur service is permitted. The TV broadcast covers a much wider bandwidth than the radar operation and can be quite sensitive to interference (the video channel is much more sensitive to interference than the audio channel). In Figure 5 the required interference suppression (according to CCIR) is shown for a TV channel. It is noticed that the requirements are most strict

Table 3. a) National frequency allocation plan of United States.
b) Amateur radio band plan (50 MHz).

UNITED STATES

Band MHz 1	National Provisions 2	Government Allocation 3	Non-Government Allocation 4	Remarks 5
39.00-40.00	NC US94		LAND MOBILE	Public safety
40.00-42.00 (ISM 40.68	C 236 US94 US210 US220 0.02 MHz)	FIXED MOBILE		See Section 4.3.6 of the Manual for Channeling Plan.
42.00-46.60	NC		LAND MOBILE	42.00-42.95 Public safety 42.95-43.19 Industrial 43.19-43.69 Domestic public/Industrial/ Public safety 43.69-44.61 Land transportation 44.61-46.60 Public safety
46.60-47.00	C	FIXED MOBILE		See Section 4.3.6 of the Manual for Channeling Plan.
47.00-49.60	NC		LAND MOBILE	47.00-47.43 Public safety 47.43-47.69 Public safety/Industrial 47.69-49.60 Industrial
49.60-50.00	C	FIXED MOBILE		See Section 4.3.6 of the Manual for Channeling Plan.
50.00-54.00	AMATEUR US1		AMATEUR	
54.00-72.00	NC		BROADCASTING	Television broadcasting

AMATEUR BANDPLAN

Segment	Frequency (MHz)	Calling frequencies
	50.00	
CW and beacons		
	50.08	
CW only		
	50.10	
All "narrow band" modes (cw, ssb, am, rtty, sstv, etc.)		50.110 — dx calling 50.200 — ssb calling 50.600 — rtty calling
	51.00	
Pacific "dx/window" (narrow band only)		
	51.10	
All modes, including fm (and repeaters)		
	52.00	
Pacific "dx window" (narrow band only)		
	52.10	
All modes, including fm (and repeaters)		
	54.00	

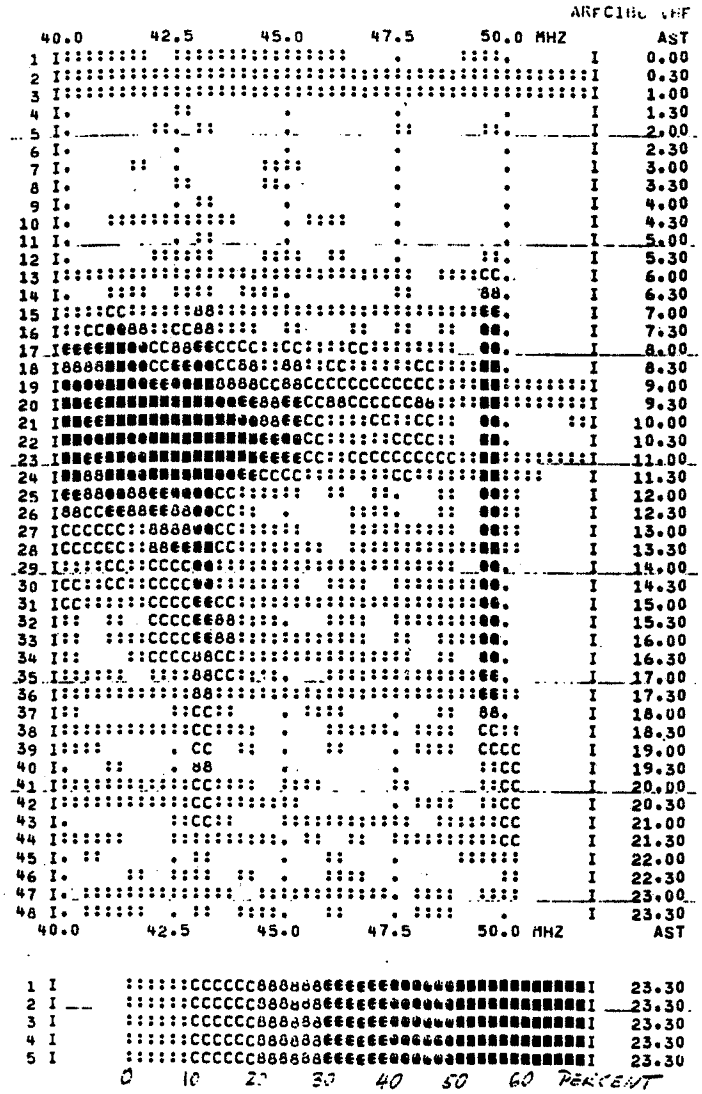


Figure 3. Occurrence of signals as function of time of day (AST) and frequency at the Arecibo Observatory in December 1979 and January 1980.

at frequencies close to the video, colour and audio carriers.

Extensive field and laboratory measurements, which were done in preparation of the licence application phase of the SOUSY-VHF-Radar in W. Germany, showed that radar operation in a TV channel is possible without causing mutual interference. It was shown that a radar operation (centrecarrier) frequency f_r = 53.5 MHz, i.e. a frequency between the colour and the audio carrier, causes the least interference to TV reception. Also a frequency just at the lower limit of a TV channel (e.g. f_r = 54.0 MHz) can be acceptable. According to the subdivision of TV-band I into channels, the video carrier frequencies

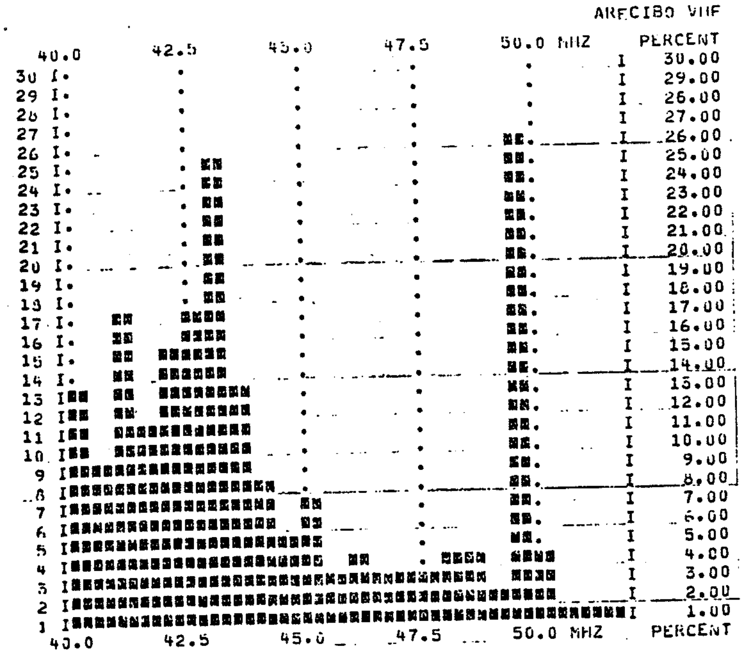


Figure 4. Cumulative distribution of interference (summary of Figure 3).

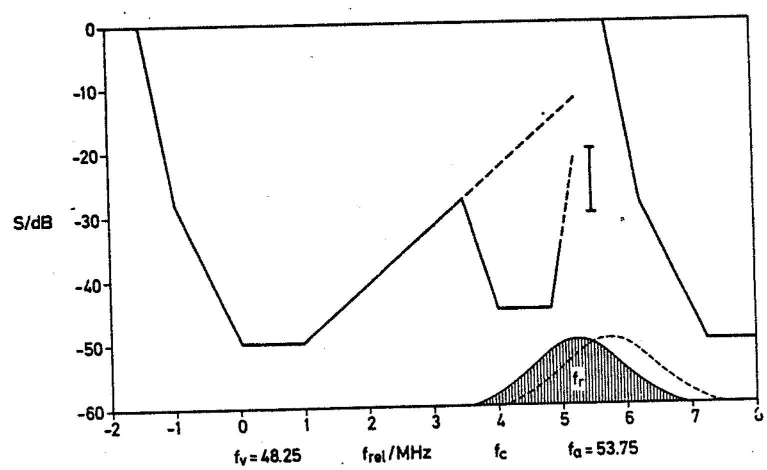


Figure 5. Interference suppression required for a TV channel (CCIR norm).

are at f_v = 48.25, 55.25 and 62.25 MHz. Radar operation (centre) frequencies $f_r = f_v \mp 5.25$ MHz or $f_r = f_v - 1.25$ MHz are accordingly most suitable.

Further field measurements made during the early operation of the SOUSY-VHF-Radar (f = 53.3 MHz, in a channel used by a TV-broadcast station at 160 km distance) did not indicate any interference to TV users. It even was found that the radar signal was no more detectable (because of mountain shielding and sidelobe suppression) at some 10 km distance from the radar. Occasional increases of noise level observed with the SOUSY-VHF-Radar might have been caused by increased TV field strength at the radar site during enhanced tropospheric propagation conditions. Very short-term interference (seconds to minutes duration), observed very rarely, was attributed to mobile stations in the vicinity of the radar. During summertime also TV signals from southern Europe occasionally occurred through reflection at sporadic-E layers.

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RECOMMENDATION

SITE SELECTION

Noticing that

(1) for a variety of meteorological investigations influences of orography are a disturbing factor,
(2) clutter and interference is mostly experienced to be minor problem,

the notion is supported

to preferably locating MST radars in flat terrain rather than in mountainous regions (excluding, obviously, research on orographic influences on meteorological phenomena).

RECOMMENDATION

FREQUENCY ALLOCATION

Noticing that

(1) Licenses to operate VHF/UHF radars are granted by national authorities in a cooperative manner, and operation has to be on a noninterference basis.
(2) Crucial interference due to radar operation has not yet been reported.
(3) The number of VHF/UHF radars used for research purposes has already increased and obviously will steadily increase, and these radars may even be included in operational meteorological systems which will increase their number explosively.

It is recommended that formal steps shall be undertaken to form a special study group of CCIR to collect experiences and define requirements and standards to facilitate negotiations with the licensing authorities and to introduce these operations officially into an internationally accepted fre-euency allocation scheme.