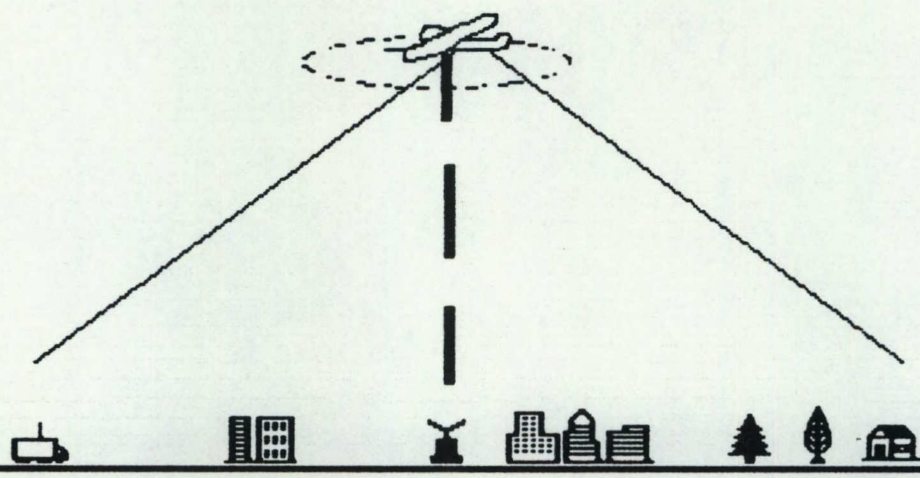
REPORT: SPECTRUM CONSIDERATIONS FOR SHARP

(A Research Discussion Paper)

Task 2: Compatibility of Proposed Services With Existing/Planned Uses of the Spectrum, And With Operation of the On-Board Rectenna



S H A R P

DSS Contract: 12ST.36001-4-1788

FOR: DEPARTMENT OF COMMUNICATIONS

FROM: ANDREW T. SCHINDLER & ASSOCIATES INC.

December 19, 1984

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LETTER OF TRANSMITTAL

December 19, 1984.

Department of Supply & Services,
Department of Communications.

Attention: Mr. G. Chan, Scientific Authority, DOC
Ms. E. Audit, Procurement Manager, DSS

Subject: Contract No. RN: 36001-4-2788

Serial No: OST84-00303

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Entitle: Spectrum Impact on SHARP (Task 2)

We are pleased to submit ten copies of Task 2 Report, on the compatibility of proposed SHARP services with existing/planned uses of the radio spectrum and with the operation of the on-board rectenna.

Yours truly,

ANDREW T. SCHINDLER & ASSOCIATES INC.

A. T. Schindler,
President.

ATS/ds
Encls.

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2.0 SERVICES THAT EITHER RECEIVE INTERFERENCE FROM SHARP, OR CAUSE INTERFERENCE TO SHARP, BASED ON CO-CHANNEL INTERFERENCE ONLY

2.1 General Methods of Avoiding or Minimizing Co-channel Interference

Co-channel interference as interpreted in this report occurs when a radio station experiences interference from another station operating on the same channel.

The effect of such interference depends on a number of factors, some of which can be controlled by appropriate measures:

a) Relative transmission power of the wanted and unwanted sources;

b) Relative path losses between the user's station and the two sources;

c) Directivity (gain as a function of direction in space) of the two sources of radiation and directivity of the user's station;

d) Polarization of the wanted and unwanted signals;

e) Sensitivity of the wanted type of signal, (e.g.

type of modulation) against the particular type and strength of the interfering signal.

If, for example, a) and b) are given, an appropriate choice of c) and d) may permit a minimization of the interference effect, and further the whole system may be designed in such a way that the interfering signal causes minimal deterioration of the wanted signal. An example of the latter is the frequency off-set used in locating VHF and UHF vestigial sideband television transmitters relative to each other in order to minimize co-channel interference to users exposed to both sources. Another example is the interstitial frequency plan used on geostationary satellite transponders in order to double the number of FDM wideband channels within the transponder passband (usually coupled with polarization discrimination).

In the following paragraphs the various proposed SHARP services, described in Task 1, will be discussed with regard to co-channel interference with other existing/planned telecommunication services. A distinction will be made (sections 2.2 and 2.3) between unidirectional and bi-directional services, depending on whether users of SHARP services receive only or also transmit radio signals. In the case of unidirectional services all radiation, that may be in conflict with other services would originate from the SHARP location including its various fixed up-links, whereas in the case of bi-directional services possible interference may originate from user locations anywhere throughout the large SHARP coverage agea.

2.2 Unidirectional Services

Broadcasting services are by definition unidirectional. In a SHARP system the signal to be broadcast is sent on fixed up-link connections to the SHARP platform, and from there distributed throughout the SHARP coverage area. VHF-FM Sound broadcasting, UHF Vestigial sideband TV broadcasting (referred to as UHF-AM TV), SHF-FM direct to home broadcasting, fall into this category. Similarily, paging services are unidirectional, with the paging message being sent to the SHARP platform via fixed up-link connections, and then forwarded in a broadcast fashion throughout the coverage area. Another type of unidirectional service is the microwave power beam which carries power from the ground to the SHARP aircraft, aided by fixed up- and down-links for control and superivision of aircraft and platform functions.

2.2.1 VHF-FM Sound Broadcasting

The case of VHF-FM sound broadcasting in the conventional frequency band 88 - 108 MHz, with 100 channel allocations of 200 KHz bandwidth, has been discussed in Task Report 1.

SHARP equipment would be designed to provide the same field strength and signal-to-noise receiving conditions over the SHARP coverage area as the conventional radio station system over the respective zones of coverage. Where the two coverage areas overlap no differentiation between SHARP and conventional services could be made using directivity and polarization (FM reception by portable radios and car radios!). Further, the path loss conditions for a receiving set relative to the conventional radio stations and to the SHARP location would vary widely depending on location and fading conditions. Therefore sharing of channels by the two systems cannot be considered. The Task 1 report concluded that special channel assignments to SHARP system would be required, and reference was made to the present Canadian FM Broadcasting Allotment Plan (Aug. 1, 1984) which lists over 2000 channel allotments to specific locations. The number of actual station assignments is at present around 750. The question of the availability of specially reserved channels under these conditions has been looked at for the example of the three Prairie Provinces, Alberta, Saskatchewan and Manitoba. A SHARP 500 km. radius coverage pattern, if located sufficiently far North to avoid penetration into the United States, would cover the main parts of two neighbouring Provinces (see map in Task 1 report). Table 1, which is extracted from the above mentioned Allotment Plan, would indicate that there are some channels (7 for Manitoba plus Saskatchewan, 3 for Saskatchewan plus Alberta) out of a total of 100 channels, which could be reserved specially for SHARP applications. This supports the statement in Task 1 report (Section 1.1.4.1)......"in conjunction with the present system would restrict SHARP to a few channels filling out existing gaps".

Co-channel interference would then be restricted to interference between SHARP installations which in general would require a 1200 km. separation, exept where topographical conditions provide some shielding.

#	MAN	SASK	ALTA	#	ALTA	MAN	SASK
201	3	5	4	251	1	1	2
2	2	6	1	52	2	1	-
3	2	3	2	53	2	-	1
4	-	3	1	54	1	1	-
5	4	1	3	55	1	-	1
6	-	3	1	56	1	3	3
7	2	4	2	57	3	-	-
8	2	2	1	58	2	1	1
9	2	3	1	59	1	-	1
10	3	4	1	60	1	7	1
11	1	1	2	61	1	-	1
12	2	1	-	62	1	1	1
13	-	-	3	63	3	2	1
14	3	4	1	64	3	2	2
15	1	3	2	65	1	1	2
16	1	4	1	66	1	2	1
17	1	4	4	67	1	1	1
18	1	4	1	68	1	3	2
19	2	4	2	69	-	1	1
20	1	4	2	70	2	-	1
21	1	1	2	71	2	1	1
22	-	1	-	72	-	1	1
23	-	1	2	73	4	-	-
24	2	-	2	74	1	1	1
25	2	1	2	75	2	-	1
26	-	-	-	76	2	1	2
27	-	2	3	77	1	-	2
28	1	2	-	78	3	1	3
29	2	2	1	79	3	-	1
30	-	1	3	80	2	2	1
31	2	3	3	81	2	-	1
32	2	2	2	82	3	3	-
33	2	3	2	83	2	2	2
34	1	1	1	84	2	1	-
35	-	2	1	85	1	-	1
36	1	1	1	86	1	5	3
37	-	1	-	87	2	2	-
38	6	2	2	88	1	1	2
39	1	3	2	89	-	-	-
40	2	1	1	90	2	1	4
41	3	-	-	91	2	1	-
42	-	-	1	92	3	1	2
43	1	3	-	93	1	-	-
44	1	1	1	94	1	1	2
45	-	3	3	95	1	1	-
46	1	1	-	96	1	1	2
47	-	2	3	97	1	-	1
48	1	1	3	98	-	2	2
49	-	1	2	99	2	-	1
50	2	2	5	300	2	5	4
	67	106	83		80	63	63

Can. FM
Broadcasting
Allotment Plan
1 Aug. 1984

100 Channels
#201 to 300

Man. - 130 All.

Sask. - 160 All.

Alta. - 163 All.

No Allotment for
Channels in:

Man. 29
Sask. 14
Alta. 12

MAN/SASK 7

SASK/ALTA 3

MAN/SASK/ALTA 2

TABLE 1

The up-links which would carry the signals to be broadcast in this service would operate in the upper SHF or lower EHF bands. They constitute fixed links of a path length not too different from conventional microwave links, and would make use of "Fixed" service frequency bands as listed in Task 1 report. Directivity of the up-link antennas could be high if tracking to the SHARP aircraft movement is employed. Coordination procedures with other terrestrial fixed services in the vicinity of the SHARP site would have to be followed.

2.2.2 UHF-AM Television Broadcasting

Task 1 report referred to the difficulties of introducing conventional UHF Television broadcasting into the list of services to be delivered from SHARP platforms. In order to meet broadcasting requirements throughout the SHARP coverage area even for a small number of channels, primary power, weight and size requirements would exceed payload limitations at least in the earlier stages of implementation. As far as spectrum utilization is concerned it appears that special channels would have to be assigned to SHARP because co-channel operation in conjunction with the terrestrial broadcasting system would be difficult to achieve in view of the density of terrestrial station assignments. The standard procedure of frequency off-setting for minimization of co-channel interference in overlap areas would give only limited relief in special cases because of the large coverage area of SHARP transmission which may allow coordination in one area but not in others. Similar to the case of VHF-Sound-Broadcasting (Section 2.2.1) the present Canadian Television Channel Allotment Plan (1st March, 1984) was analyzed for the three Prairie Provinces, Manitoba, Saskatchewan and Alberta. Assuming SHARP coverage of two neighbouring Provinces the plan (Table 2) shows a very limited chance of obtaining special channels within the used portion of the spectrum (channel 14 to channel 54). However, at present channels from #55 to #69 would be essentially free to be reserved for SHARP in this area

Regarding the up-link conditions for carrying the TV signals up to the SHARP platform the same consideration apply as in the case of FM-Sound broadcasting (Section 2.2.1).

UHF TV Canada: Allotments and Assignments, March 1, 1984

Ch#	ALTA	MAN	SASK
14	3	5	6
15	4	4	6
16	6	-	3
17	4	3	2
18	2	3	2
19	6	4	4
20	4	-	1
21	2	2	4
22	3	3	5
23	3	2	2
24	5	2	3
25	3	2	3
26	3	2	5
27	2	2	4
28	2	4	2
29	-	4	4
30	4	-	1
31	5	1	1
32	3	2	2
33	1	1	2
34	5	3	2
35	2	1	-
36	1	1	3
37	-	-	-
38	2	1	1
39	1	2	1
40	-	3	1
41	5	6	3
42	3	2	1
43	-	2	1
44	3	-	-
45	2	2	2
46	1	2	2
47	3	5	1
48	3	4	1
49	4	1	1
50	1	2	-
51	2	-	-
52	1	1	-
53	3	3	2
54	2	2	5
55	-	-	-
56	-	-	-
57	1	-	-
58	-	-	-
59	-	-	-
60	-	-	-
61	-	-	-
62	-	-	-
63	-	-	-
64	-	-	-
65	-	1	-
66	-	-	-
67	-	-	-
68	-	-	-
69	-	-	-

#14 to #69: 56 channels total
#14 to #54: 41 channels used

	Station Allotment	No Allotment
ALTA	110	4
SASK	88	6
MAN	88	6
ALTA/SASK	198	1 (Ch.#37)
SASK/MAN	176	3
ALTA/SASK/MAN	286	1 (Ch.#37)

Channels 55 to 69 not used (with 2 exceptions) in any of the three Provinces

TABLE 2

2.2.3 Paging

As in the case of broadcasting discussed in the two preceding sections, paging services also require special frequency assignments within the SHARP coverage area, since methods for avoiding co-channel interference with other terrestrial or satellite paging services in the same frequency band are not applicable.

Regarding up-link connections for carrying the paging signals up to the SHARP platform see Section 2.2.1.

2.2.4 SHF-FM-TV and Sound Broacasting

From the point of view of the earth station user, this service is similar to the services from direct-to-home broadcasting satellites and the technology used can be identical, except for the receiving dish size in certain areas.

SHF frequencies offer the possibility of using high directivity receiving antennas and polarization discrimination, which can alleviate co-channel interference problems between SHARP service and any other service sharing the same frequency band.

There are a number of options for the selection of a suitable down-link frequency band which differ in their characteristics regarding co-channel interference.

2.2.4.1 The first option is the band 11.7 to 12.2 GHZ, which is allocated to fixed-satellite and broadcasting-satellite services (with certain restrictions). As mentioned in Task 1 report (Section 1.2.5) this band is likely to be used by the Canadian DBS system, and the suggestion has been made that users of SHARP could be able to use their equipment alternatively for either one of the services. The avoidance of co-channel interference would be based essentially on path geometry conditions, aided possibly by polarization discrimination. Figure 1 shows the path geometry: Earth stations A, B, C, D, E receive signals from both, SHARP, and the DBS satellite. Only for station D the radiation from SHARP and satellite would come from the same direction, i.e. co-channel interference would occur unless polarization and/or frequency plan arrangements would suffice to minimize the effect. If the SHARP location is north of the main population area conditions as those for station D would apply to less populated areas and an appropriate choice of the SHARP location could minimize the effect. (DBS type 1 m. dishes have 1.7^{o} beamwidth (3 db points), so that small changes in the angular position of SHARP would be effective by moving the interference zone to more acceptable locations.

The determination of zones and levels of co-channel interference is complicated by the fact that SHARP signal strength - in contrast to that of satellite signals - varies over the coverage area, being strongest near the centre point of the SHARP system, and diminishing towards the edge of coverage. Near the edge of coverage there is a further deterioration of SHARP signals due to multipath effects, shielding at low angles etc. (For the latter reason the operational range of SHARP is considered to be around 300 km (3 to 4^{o} of elevation angle) rather than the horizon distance of 500 to 600 km.).

Figure 1 shows the free space loss at 12.5 GHz as a function of distance from the SHARP centre point (neglecting multipath and shielding effects). In order to be compatible with the DBS system, SHARP equipment would be designed to produce the same minimum flux density at the largest operational distance (300 km.) as that from a DBS satellite. Therefore, at shorter distances SHARP signals would always be stronger than DBS signals, and avoidance of co-channel interference would require - besides polarization discrimination - discrimination by the directivity of the receive antennas. In order to limit the margin for such discrimination, i.e. avoid excessive signal strength of SHARP compared to DBS, the SHARP transmit antenna pattern could be shaped, so that the EIRP would be maximized in direction of the horizon or the 3 to 4^{o} depression angle, and gradually reduced toward larger depression angles. This would require stabilization of the SHARP platform against banking of the aircraft during its circular movement. As an example of beam shaping, curve (2) in Figure 1 shows the effect of such a reduction of signal strength assuming a 10 db taper from the 3 to 4^{o} depression angle to the 90^{o} angle (underneath the SHARP platform).

A further complication arises from the SHARP aircraft movement. Non-tracking receiving dishes in close vicinity to the SHARP centre point must be small enough (wide angle pattern) to cover the aircraft movement. This has two consequences:

Firstly gain is reduced, which is not objectionable because it occurs in an area where the flux density is highest. In the example of curve (2) in Figure 1 a 13 db reduction underneath the SHARP platform (distance 0 from SHARP centre) could be tolerated, corresponding to a reduction of the dish diameter from 1 m. to 22 cm. Such a reduction corresponds to an increase of the receive antenna beamwidth from 1.7° (at 12.5 GHz) to 7.6° (3 db points);*

The second consequence is the reduction in directivity discrimination which would increase the area of co-channel interference between SHARP and DBS services (station C in Figure 1).

The conditions are rather complex, depending on many design parameters of the DBS and SHARP systems. In

* This would be enough to cover a circular aircraft path of 1 km. radius (stated in some documentation), but not that of 2 km. radius (stated in most of the available documents).

order to indicate some of the complexity, Table 3 shows the (simplified) analysis of a model for a SHARP system with and without 10 db beam shaping (Figure 1), but neglecting fading.

In conclusion of this discussion on co-channel interference between SHARP and DBS broadcast services, occupying the same frequency band and the same channels, it appears that

- with appropriate beam shaping of the SHARP transmit antenna, mounted on a stabilized platform, it should be possible to control the flux density of SHARP signals relative to those from a DBS service to the extent that directivity discrimination of the receive antennas possibly in combination with polarization discrimination would allow independent operation throughout most of the SHARP coverage area,

- there will always be zones where the direction of arrival of DBS signals is so close to that of SHARP signals, that directional discrimination cannot be used to minimize co-channel interference. These zones can be located in areas of minimal effect on customers by appropriately locating the SHARP installation.

- the zone underneath the SHARP platform (within a radius of up to 100 km.) causes problems for using non-tracking receive antennas because of the SHARP aircraft movement. Since SHARP flux density is highest in this zone a compromise between beam shaping and receive antenna directivity is required which may not be possible to maintain under practical conditions (platform stabilization, stability of aircraft movement etc.). It seems preferable to exclude the zone underneath the SHARP platform from consideration as "coverage area", and have it serviced from an adjacent SHARP. This would, of course, require the use of different sets of channels for the two SHARPs within the same frequency band. The omission of the central zone would give the SHARP operational coverage the shape of an annular ring with the advantage that the spread of flux density throughout the remaining coverage area is reduced which would make equalization of flux density by beam shaping more practical.

With regard to interference from fixed-satellite down-links into SHARP service such links operate in general at lower flux density levels than DBS links, so that their contribution to co-channel interference with SHARP down-links can be neglected as long as the SHARP design is based on flux density levels comparable to those of DBS.

Regarding co-channel interference from SHARP service into fixed-satellite down-link operations directivity discrimination of the fixed satellite earth station, and appropriate siting of the SHARP locations relative to the fixed earth station should be able to provide sufficient protection. Again, as discussed in connection with Figure 1, an appropriate shaping of the SHARP transmit antenna pattern is important to avoid excessive flux density levels.

2.2.4.2 A second option could be the band 12.2 to

12.7 GHz allocated to "fixed services, broadcasting-satellite services". As long as SHARP service is designed to provide flux density levels not exceeding those of broadcasting-satellite services, standard coordination procedures for sharing of frequency bands between satellite and terrestrial services would apply. If, however, as has been suggested, SHARP services would use higher flux throughout its coverage area in order to use smaller receiving dishes (such as 25 cm. diameter), sharing with terrestrial microwave links could raise insurmountable coordination problems. As in the case discussed in the preceding section, equalization of the SHARP flux density levels is important.

2.2.4.3 As a third option for SHARP SHF-FM broadcast services it was suggested to use the band 14 to 14.5 GHz which is allocated to "fixed-satellite (earth to space)" services. This option was analyzed in Ref. 1. with the result that interference from the SHARP platform into a geostationary satellite uplink receiver is negligible but that in the vicinity of a satellite up-link installation interference into a SHARP receiving set could be significant for certain locations of the receiving set.

2.2.4.4 Regarding up-link connections for carrying the broadcast signals up to the SHARP platform, see Section 2.2.1.

2.2.5 Operation of the Microwave Power Beam and the On-board Rectenna

The proposed microwave beam, transmitting power from the ground to the SHARP aircraft operates in one of the ISM (Industrial, Scientific and Medical) bands at a suitable spectrum location where on one hand the antenna size is not excessive, on the other hand atmospheric (rain) attenuation is sufficiently small. In the list of ISM bands (see Table 3) the only two suitable spectrum locations are in bands 2400 to 2500 MHz (centre frequency 2450 MHz) and 5725 to 5875 MHz (centre frequency 5800 MHz). Since these bands are not available to any telecommunication services direct "co-channel" interference cannot occur.

TABLE OF ISM FREQUENCY ALLOCATIONS

Non-Telecommunication Frequencies

Industrial, Scientific and Medical (ISM)

Lower Frequency Limit	Upper Frequency Limit	Center Frequency
13 553 kHz	13 567 kHz	13 560 kHz
26 957 kHz	27 283 kHz	27 120 kHz
40.66 MHz	40.70 MHz	40.68 MHz
902 MHz	928 MHz	915 MHz
2 400 MHz	2 500 MHz	2 450 MHz*
5 725 MHz	5 875 MHz	5 800 MHz**
24 GHz	24.25 GHz	24.125 GHz

*Frequency considered for SHARP

**Frequency preferred for SHARP

TABLE 3

However, spurious frequency components including harmonics that accompany the main SHARP microwave beam and the rectenna operation may fall into telecommunication service bands.

Figure 2 gives a simplified representation of the power beam. At ground level is a microwave transmitter to generate some 100 to 1000 KW microwave power which is fed to a radiating device which radiates a vertical beam towards the SHARP aircraft. The radiating device is shown as a single dish, but may consist of an array of dishes which are fed in proper phase relationships. The microwave radiation is focussed into an area of about 30 m. diameter at the height of 21 km., the average height of the circling aircraft. The focussing process keeps the total microwave energy contained in a column of about 30 m. diamater so that the loss between the ground antenna and the illuminated area at the 21 km. level is very small. Beyond that level the microwave beam is widening out into the typical far-field pattern of directional antennas corresponding to a $.1^{\circ}$ beam (3 db points).

Since the aircraft at the 21 km. level is circling in a circle of about 2 km. radius the microwave beam has to be tracked to the moving aircraft.

The aircraft carries a rectenna, which is an arrangement of several thousand dipoles connected to rectifiers (diodes) which convert the microwave power (500 W/m2) into DC at high efficiency (85 to 90%). The present aim is to produce 20 KW DC power. Apart from the r.f. to DC conversion the rectifiers produce harmonics, which, depending on design, are partly radiated from the rectenna. Figure 2 gives some experimental results of rectenna studies (typical test results which are still subject to improvements).

From a radiation point of view the whole microwave beam-rectenna system is shown in simplified form in Figure 3.

Table 4 lists the second, third, fourth and fifth

HARMONICS OF ISM BAND

Fundamental GHz	2nd Harmonic	3rd Harmonic	4th Harmonic	5th Harmonic
2.4 - 2.5	4.8 - 5.0	7.2 - 7.5	9.6 - 10.0	12.0 - 12.5
Centre 2.45	4.9	7.35	9.8	12.25
	Fixed Service Radio Astronomy Space Research (passive)	Fixed Service Fixed Sat. Service (space - earth) Mobile Sat. Met. Sat.	Radio Location	Fixed Sat. Service (space - earth) Fixed Service Broadcast Sat. (space - earth)
5.725-5.875	11.45-11.75	17.175-17.625	22.9 - 23.5	28.625-29.375
Centre 5.8*	11.6	17.4	23.2	29.00
	Fixed Service Fixed Sat. Service (space - earth)	Radio Location Space Research FSS and FBS Feeder Links	Broadcast Sat. Fixed Service Inter-Satellite Mobile Radio Astronomy (23.07 - 23.12)	Fixed Service Fixed Satellite Service (space - earth) Mobile

*Preferred frequency for SHARP

TABLE 4

harmonics of the two above-mentioned ISM frequency bands, together with telecommunication service allocations that fall into the same frequency bands. A more quantitive treatment of the effects of these harmonics is the subject of Task Report 3.

For a number of reasons it appears that the option of a microwave beam operation in the 5.8 GHz band is favoured over that in the 2.4 GHz band. Antenna size and costs of the tracking ground installation are the main reasons. From the point of view of harmonic frequency interference into other telecommunication services the higher band is also preferred to the lower one (see also Ref. 2). For example in the 4.8 to 5 GHz band, the second harmonic of the 2.45 GHz ISM band, there are a number of important radio astronomy lines in the 4825 to 4835 MHz region. In this respect ITU Radio Regulation 2903 states: "...Administrations are urged to bear in mind that the radio astronomy service is extremely susceptible to interference from space and airborne transmitters". This applies, of course, not only to the exact second harmonic freqency of the rectenna radiation but also to the spurious emissions that may be present in this radiation.

As a result it appears that the 5.8 GHz option is the main one to be considered for SHARP power beam operations.

2.2.6 Up- and Down-Link Fixed Connections

A number of up- and down-link connections between base stations and the SHARP platform are required on one hand for control and supervision of the aircraft operations, on the other hand for conveying signals to and from the various telecommunication equipments located on the platform. As mentioned already in Section 2.2.1 these links are not unlike conventional fixed microwave links of between 20 and 50 km. path length, likely to be equipped with tracking ground station antennas to allow high directivity and low power. Frequency bands will be in the upper SHF, lower EHF range as mentioned in Task 1 report.

With regard to interference with other fixed link operations conventional coordination procedures apply.

2.3 Bi-Directional Services

2.3.1 Two Way Voice and Data Fixed and Mobile Service

2.3.1.1 UHF

The use of the band 806 - 960 MHz for SHARP two-way narrow band services had been considered with a view towards compatibility with existing fixed and mobile systems, in particular the cellular system for mobile telephony. In that case channel arrangements have to be co-ordinated with those of the existing systems, limiting co-channel interference to acceptable minimum levels. Though SHARP links are line-of-sight paths, their reliability near the edge of coverage is low, i.e. the fading margins to be allowed in the interference calculations increase as the path elevation angle approaches zero. For that reason paths with less than 3 to 4^{o} of elevation (more than about 300 km.) should be excluded from operational use wherever reliability is of primary importance. However, for interference calculations the frequency re-use distance has to be based on the actual radio horizon, (about 600 km.).

With regard to the calculation of co-channel interference levels the applicable fading margins are of importance because in some cases the main and the interfering path may experience the same fading effect, in other cases the fading for the two signals may be independent. The former is the case where for example frequency re-use is achieved by sectoral pattern division on the SHARP platform. Then the side lobe radiation from one sector may interfere at a low level with the main lobe radiation from another sector, but both sources of radiation undergo the same fading when reaching the receiving station. The other extreme may take place in the interference between two SHARP platforms, when one of the interfering paths may experience fading, the other not, in which case the fading margin has to be added to the initial level of interference.

2.3.1.2 Upper UHF and SHF

If no compatibility with existing systems is required other frequency bands may be used for example in the category of Fixed Service for which there are allocations above 100 MHz as shown in the Annex*. If special assignments for SHARP

*At present these bands are allocated to Fixed Services only. It may be possible to add mobile services within Canada.

can be found co-channel interference would be limited to that occurring by frequency re-use between SHARP platforms, or within any one platform.

The higher the frequency the more likely are multipath effects at the edge of coverage, specular reflection and shielding by buildings, trees, etc., and the more important is the clearance of the line of sight between the receiving station and the SHARP platform. From a design point of view higher frequencies would remove some of the difficulties in the design of sectoral splitting of the horizontal SHARP antenna pattern to gain frequency re-use provided that platform stabilization in azimuth (de-spinning as the aircraft flies on its circular path) and in the horizontal plane (compensating for aircraft banking) can be solved. Another constraint introduced by sectoral splitting of the antenna platform is that the zone directly underneath the SHARP platform has to be excluded from the coverage area. The remaining area then is confined to the shape of an annular ring limited towards the centre by a centre zone of about 100 km. radius, towards the horizon by the limit of reliable reception conditions (elevation angles of not less than 3 to 4^{o}). However, for frequency coordination purposes the whole area from centre to horizon has to be considered.

The choice of a frequency band higher than the much used 806 - 960 band may also have the advantage that the available bandwidth would allow the use of a wider bandwidth modulation method (e.g. digital instead of SSB) to improve the quality of voice and data services.

2.3.2 Two-Way Video Service

Apart from the required bandwidth, two-way video service to customers throughout the SHARP coverage area is similar to the two-way narrow band services discussed in Section 2.3.1. In order to increase the number of available channels, sectorization of the horizontal SHARP antenna pattern has been suggested with the complications mentioned in the preceding section. Since compatibility problems with existing services of the same type do not exist special spectrum assignments above 1 GHz are required.*

*This is subject to the interpretation given in this report, that individual SHARP links represent "a radio communication service between specified fixed points" (ITU definition for Fixed Service).

In that case all co-channel interference would be confined to that which has its causes in the SHARP system itself, i.e. in the individual platform, as well as the inter-working between platforms. It appears that sectoral pattern division would present fewer and less severe problems in co-channel interference the higher the frequency band. Therefore frequencies above 10 GHz appear to be more suitable.

2.3.3 <u>Inter-SHARP Long Haul Links</u>

In long strings of SHARP platforms long haul connections can be established by direct platform to platform links, which - with sufficiently close spacing between the platforms - would pass through the upper atmosphere, where atmospheric losses (rain, etc.) are less severe. The criteria for frequency re-use for SHARP platform to ground connections would not apply. These long haul links resemble more conventional mountain top to mountain top microwave links where overreach problems are solved by a zig-zag configuration of the string of stations. Similarly SHARP strings may be arranged in zig-zag configuration. From a design point of view these links present problems because of the tolerance in the locations of the "fixed" points (SHARP aircraft height, movement and orientation). Stabilization to one tenth of a degree in azimuth may be necessary.

SHARP Model for SHF/FM/TV

Tx power 4W per channel with 10 dbi Antenna gain toward horizon

Bandwidth B = 24 MHz = +73.8 db Hz

G/T of receiver   10 db/degrees K including 2 db Loss

C/N min. 14 db (carrier to noise ratio at 300 Km with 2 db margin)

Margin M = 2.5 db for conditions at 300 km.

f = 12.5 GHz   L = 164 db at 300 km. (free space loss)

Eirp = C/N + B + L + M - G/T - 228.6 dbW

Power density P_{W/m^2} = -105 db W/m^2 at L = 164 db (300 km)

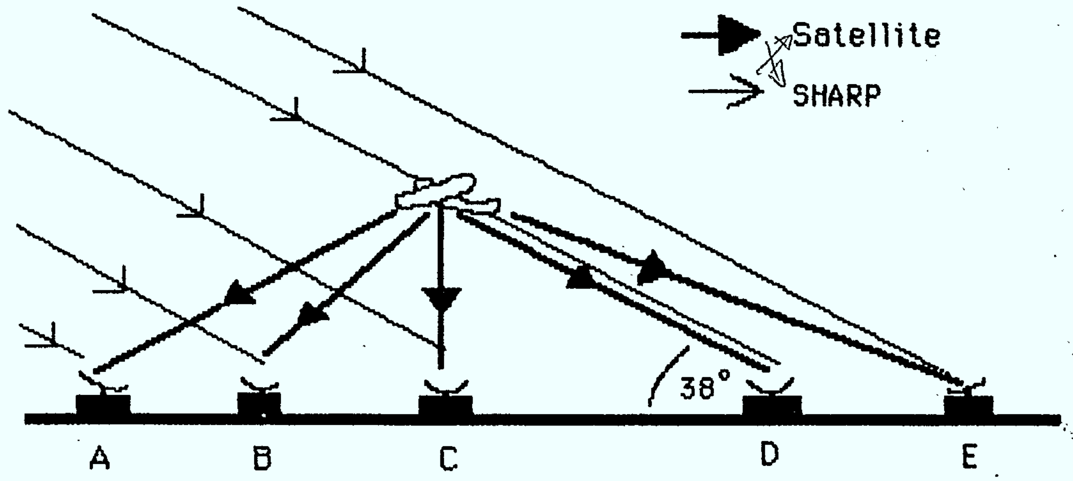
C/N of DBS with 1 m. antennas	Ratio of $(C/N_S)/(C/N_D)$ SHARP(S) to DBS(D) (non-fading)		Radio of C/N SHARP to DBS Without Beam Shaping (non-fading)	
	(a)	(b)		
+14	0	0	+0	+0
+14	+2	+2	+3	+3
+14	+5	+5	+9	+9
+14	+2	+2	+9	+9
+14	-2*	+1	+6	+9
+14	-3*	+1	+7	+11

INTERFERENCE ANALYSIS OF MODEL

TABLE 3

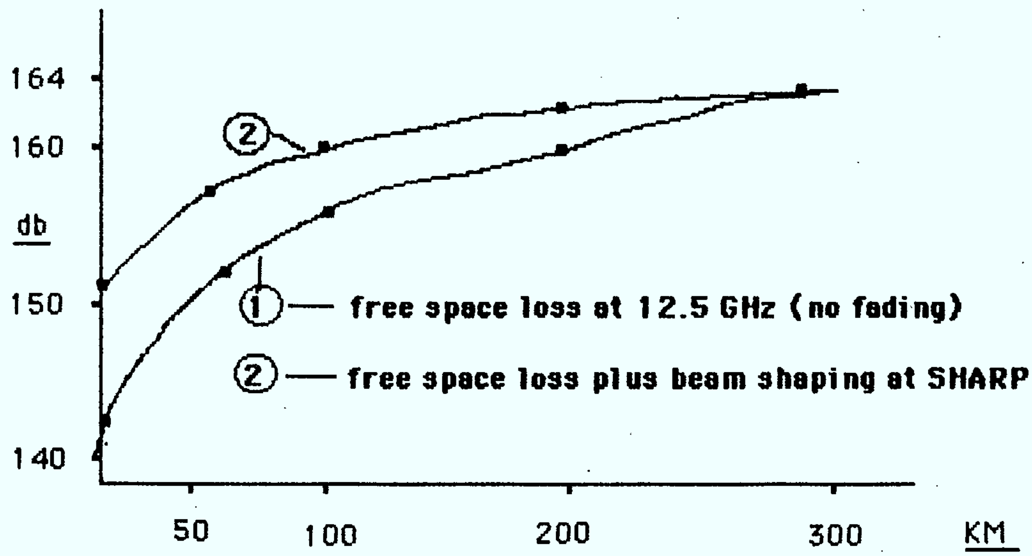
Distance from SHARP Site	Power Density Without Beam Shaping	Power Density with 10 db Beam Shaping	Receiving Dish Diameter		C/N at Receiver Dish Diameter (non-fading)		Power Density of DBS Signal
			(a)	(b)	(a)	(b)	
300 km.	-105dbW/m^2	-105dbW/m^2	1 m	1 m	14db	14db	105dbW/m^2
200	-102	-103	1	1	16	16	105
100	- 96	-100	1	1	19	19	105
50	- 90	- 97	.5	.5	16	16	105
25	- 87	- 95	.25	.35	12*	15	105
0	- 82	- 92	.15	.25	11*	15	105

*Below min. acceptable level, would require different beam shaping.



DBS-SHARP COEXISTENCE

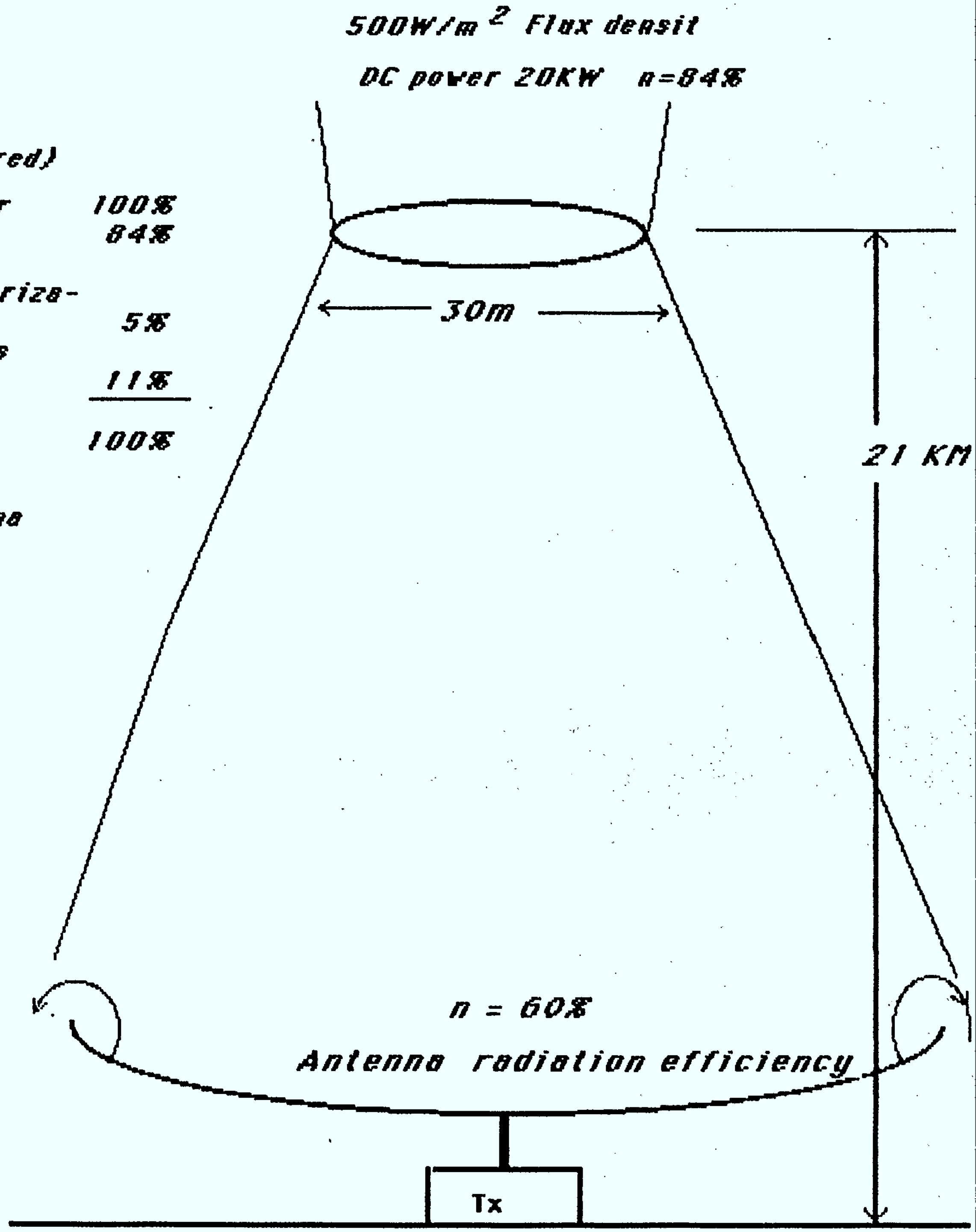
FIGURE 1



Rectenna (measured)

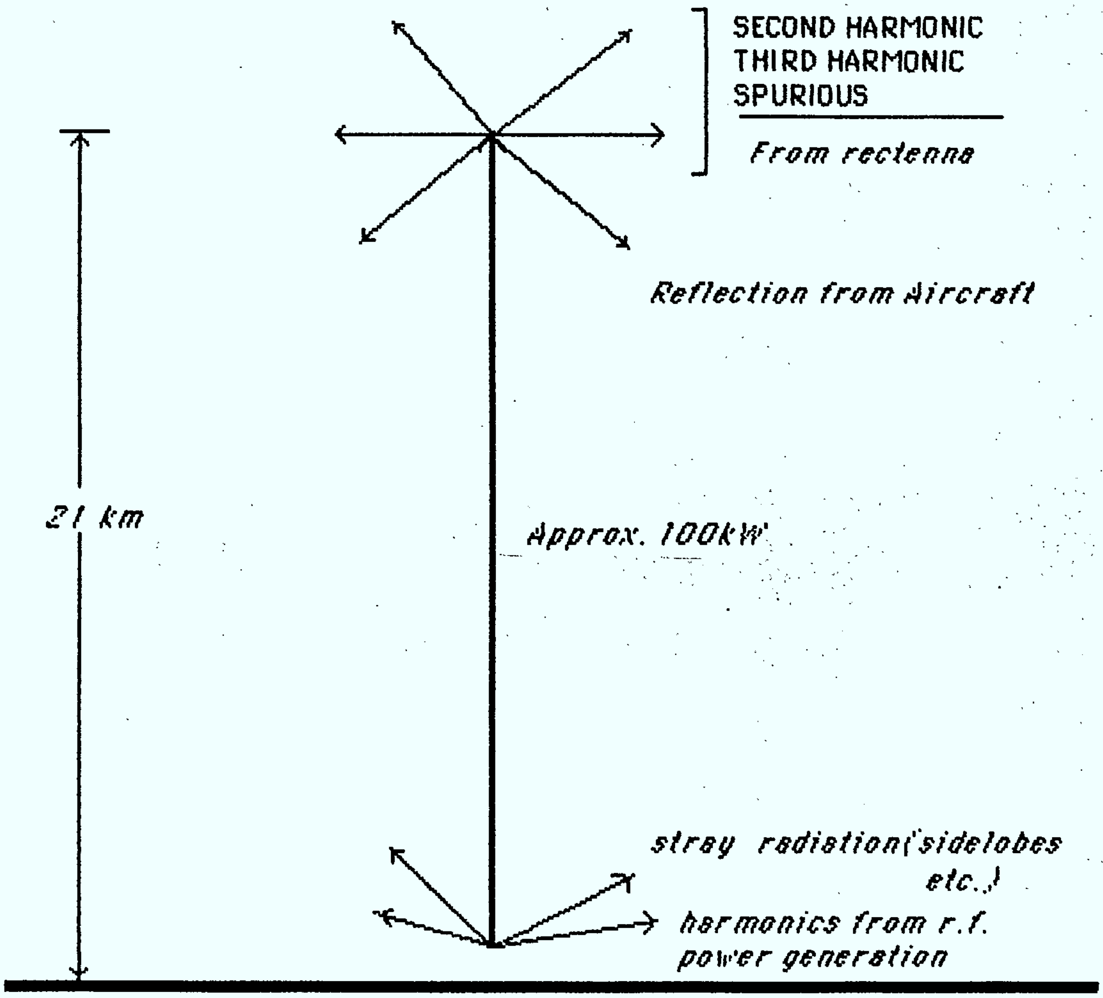
available* r.f. power	100%
DC output	84%
mismatch, harmonic, re-radiation, depolarization	5%
diode conversion loss (heat)	11%
	100%

*captured by rectenna



MICROWAVE POWER BEAM CHARACTERTISTICS

FIGURE 2



MICROWAVE POWER BEAM

SOURCES OF POTENTIAL INTERFERENCE

FIGURE 3

Frequency Allocations for Canada

Fixed Service from 1 to 15 GHz

MHz	MHz
1 427-1 429	10 500-10 550
1 429-1 525	10 550-10 600
1 525-1 530	10 600-10 680
1 530-1 535	10 700-11 700
1 660.5-1 668.4	12 200-12 300
1 668.4-1 670	12 300-12 700
1 700-1 710	12 700-12 750
1 710-2 290	12 750-13 250
2 290-2 300	14 500-14 800
2 300-2 450	14 800-15 350
2 450-2 500	
2 500-2 550	
2 550-2 655	
2 655-2 690	
3 500-4 200	
4 400-4 500	
4 500-4 800	
4 800-4 825	
4 825-4 835	
4 835-4 950	
4 950-4 990	
4 990-5 000	
5 850-5 925	
5 925-7 075	
7 075-7 250	
7 300-7 450	
7 450-7 550	
7 550-7 750	
7 750-7 900	
7 900-7 975	
8 025-8 175	
8 175-8 215	
8 215-8 400	
8 400-8 500	
9 800-10 000	

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2. Internal Memorandum
   R. J. Bibby to E. J. Hayes
   SHARP - Frequency of Operations (power beam)
   March 29, 1984   File DSS 8740-2

3. Rectenna Array Measurement Results
   R. M. Dickinson
   Jet Propulsion Laboratories

4. See also references in ATS Task 1 Report.

Discussions held during preparation of this report in the period 22 Nov. to 15 Dec. 1984.

A. Lillemark	re. general systems parameters
G. Jull	re. general systems parameters
R. Bibby	re. power beam spectrum
D. Bonnycastle	re. rectenna measurements
R. Milne	re. microwave power beam

General Project Review, meeting on 6 Dec. 1984

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