8

A PROPOSAL ON MILLIMETERWAVE COMMUNICATION AT ANTARCTICA

8.1. Introduction :

With growing activities at Antarctica, it has become necessary to have a reliable and uninterrupted communication with Indian Antarctic base station, Maitri. The success of Antarctic expedition depends largely on the availability of efficient communication system through which information and expertise may be readily accessed as and when required by the working groups. Conventional communication system, such as HF systems, can not meet this requirement. With limited bandwidth HF can not accommodate audio, video, data at a fast rate. Moreover, due to varying ionospheric conditions HF link is interrupted frequently which sometimes lasts from hours to days.

The main problem with long distance communication at Antarctica is that no geostationary satellite (GSO) is visible from the region [*Roddy*, 1989]. Polar orbiting satellite, sometimes called Earth Exploratory Satellite (EES) turns out to be the only option which can provide uninterrupted communication when a number of those are available and visible in succession over Antarctica. If a number of such satellites are allowed to orbit with a mini-mum calculated spacing between consecutive satellites, they would require a ground terminal with precision satellite tracking facility which is not required for geostationary satellites. Such a precision tracking mechanism can only be achieved at shorter wavelengths, at which a smaller and light weight steerable tracking antenna can be easily developed.

For short range communications over the ground in Antarctica, the problem is even more severe. For a VHF walkie-talkie working for a range of 5 km at Calcutta failed to work even 1 km apart at Antarctica due to heavy signal attenuation by the ice covered terrain. Antarctic ice is a complex substance whose electrical characteristics vary over a large range and propagation is anomalous [*Bourne et al.* 1970]. Electrical characteristics of sea ice was measured by *Wentworth and Cohn,* [1964] and theoretical physical models were given by *Luchininov,* [1968]. The Antarctic ice has an average thickness of 2.2 km. *Jiracek and Bentley* [1971] indicated the relative permittivity of ice to vary between 2.8-3.2 and an effective conductivity between 5×10^{-5} and 10^{-6} S/m. The relative permitti-vity varies linearly with the density of ice. Radio waves can easily penetrate the Antarctic ice and reflected by the underlying bedrock. Across the large Antarctic sea surface the presence of low conductivity ice layer over high conductivity sea water gives rise to a trapped surface wave or 'Elliott' mode. This leads to anomalous propagation characteristics of the signal in the area.

In view of the problems faced in HF and VHF bands at Antarctica, a radical solution may be obtained by moving to mm-waves which would accommodate all audio, video and data communications between hutment to hutment and hutment to ship. This would avoid depen-dence on ground wave which is adversely affected by low conducti-vity ice surface. Apart from this, reduced antenna size at mm-waves are good for fast scanning antenna system used in ground to orbiting satellite link. Therefore, the immediate challenge is to move into mm-wave systems that would work reliably in the Antarctic continent with extremely low water vapour attenuation and sparse rain events. At mm-waves, the penetration depth in ice is much less while the sharper beamwidth makes the antenna size moderate and would also allow the RF beam to be kept above the ground ice cover. In view of the above, mm-wave communication would invariably be a better alternative for Antarctica. The small and rugged system at mm-waves makes it ideal for easy portability and for the development of satellite onboard transponders with stringent restrictions on size and weight.

In this chapter, a proposal has been made for both surface to surface and surface to satellite mm-wave communication system for global connectivity. Selection of optimal working frequencies are also discussed in detail.

8.2. Scheme of satellite communication :

Owing to the fact that no geostationary satellite is visible from the polar regions, leaves polar orbiting satellite to be the single ended solution for long distance communication from Antarctica. The geometry of the problem as shown in Fig.8.1(a) demonstrates how a satellite in the geostationary orbit lies below the horizon. A more detail diagram, in Fig.8.1(b), it is observed that LOS-path is clearly obstructed by the horizon which prevents direct communication between GSO and Antarctica. An EES must be employed above the pole which should orbit within points A and B to be always visible from GSO. Thus, coumunication from Antarctica is only possible through EES which relays signal to GSO for global connectivity.

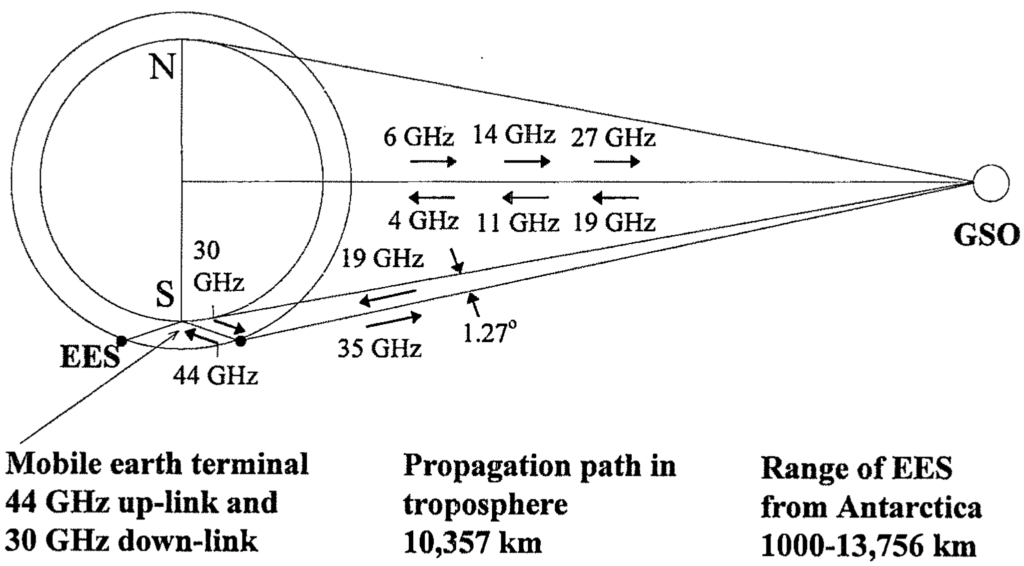

Fig.8.1(a) Geometric diagram of the positions of GSO, EES with respect to South pole

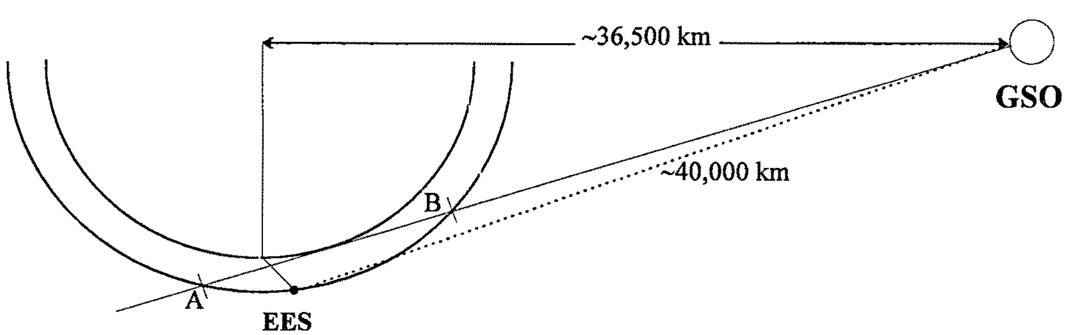

Fig.8.1(b) Detail geometric positions of GSO, EES and the pole for which GSO is not visible from the pole.

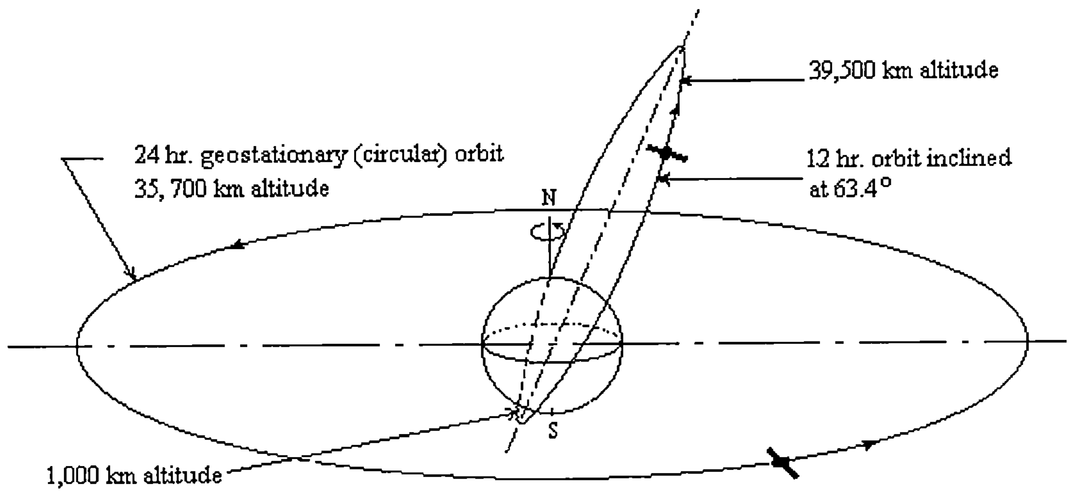

Fig.8.2. Geometric orientation of satellites in Molniya orbit

However, other orbits, such as the Molniya orbit, one of which is shown in Fig.8.2 could be an option for mobile satellite communication systems. In this orbit, the satellite can appear almost directly overhead for about 8 hours a day; a group of three such satellites are required to provide 24 hour continuous communication. Launching of such satellites for communication only with the Antarctica, would not, however be cost effective.

Polar orbiting satellite may be used in LOS mode of communication with ground terminal at the pole having precision tracking mechanism. As such satellites become visible to geostationary satellites even to those passing over the Antarctica, relaying of the information to and from Antarctica to the geostationary satellite would be possible through the polar orbiting satellite. Angular tracking requirement for such a relay communication between the polar orbiting satellite and the geostationary satellite is only 1.27^0 and the onboard antenna tracking problem would be minimal.

For communication between orbiting satellite and ground, the use of a widebeam onboard antenna at the polar orbiting satellite for ground to satellite LOS would eliminate the onboard antenna tracking requirement for the LOS link between the orbiting satellite and the ground station. In general, polar satellite remains at a relatively lower altitude (between 1000 to 13,756 km) and thus offers a time limited coverage over Antarctica and therefore, a number of polar orbiting satellites equally spaced in the orbit will be required for 24 hour coverage. The existing remote sensing satellites, which are all polar orbiting, may be utilised for ground - satellite LOS link over Antarctica.

Thus Geostationary Relay Satellite may be used to collect signal from orbiting satellite and relaying that to the ground or to the chain of geostationary satellites for global communication. The remote sensing polar orbiting satellites are often called as Earth Exploration Satellite (EES). The transponder at EES for communication with Antarctica may have a steerable antenna beam to maintain communication during a satellite pass over the Antarctica. However, due to the low altitude path loss is low and a broad beam antenna would be good enough to achieve the desired C/N ratio in the LOS link. Both the EES and GSO transponders for the EES-GSO link must have a narrow antenna beam of about 0.5^0 and two beams must remain aligned to each other. The requirement of beam alignment of such narrow beams is limited only over an angular tracking range of 1.27^0 and should not, therefore, create any problem in tracking. All these antenna tracking problems are within the capability of present day technology (*Jansky*,1983).

8.3. Scheme of surface to surface communication :

For ground to ground communication VHF band walkie-talkies are most popular for their portability, cost and ease of use. But performance of these walkie-talkies are seriously degraded at Antarc-tica. The origin of the problem is tried to be understood in the following section.

8.3.1. Problems in VHF communication at Antarctica :

VHF communication between two points on the earth is governed by two components of the transmitted signal. One is direct signal and the other is reflected signal. The reflected component may increase or reduce the signal strength received at the other end which entirely depends on the phase path of reflected ray. The reflected component will add to the signal strength if the difference of phase path reflected and direct rays is π in addition to the phase change of π on reflection at the ground over the path midpoint. The corres-ponding antenna height(h) from the ground is a function of distance between two points(r) and the wavelength(λ) of the signal and is given by

$$h = \frac{1}{2}\sqrt{r\lambda} \qquad (8.1)$$

For communication at 150 MHz, over a range of 1 km, we have r = 1000m and λ=2m and from which we obtain, using Eqn.(8.1), the effective antenna height, h = 23m. In practice, however, the height of the antenna h = 2m, the manheight and this is less than an order of magnitude lower than 23 m. Thus the antenna can be considered to almost near the ground in terms of wavelength. In general, human height varies between 1.5-2.3m. As a result, if both the transceivers are operated in the handheld mode, then ground wave will dominate. Over an icy terrain in Antarctica the ground wave range would be small as the effective ground conductivity is as low as 10^{-5}-10^{-6} S/m (CCIR Report 226-6). In contrast to this, the effective conductivity of loam soil over a tropical region like Calcutta is much higher, being of the order of 10^{-2} S/m and may become 10^{-4} only when completely dried. The propagation constant of the ground is given by

$$k = j\frac{2\pi}{\lambda}\sqrt{\varepsilon_r - j60\sigma\lambda} \qquad (8.2)$$

where ε_r is the relative permittivity, σ is the conductivity in S/m, and λ is the free-space wavelength in metres. It is the conductivity that controls the attenuation of ground wave. We may examine whether the direct ray path have got the Fresnel zone clearance for the height of the antenna in walkie-talkie. Radius of the 1st Fresnel zone b_r is given by

$$b_r = \frac{1}{2}\sqrt{r\lambda} \quad \text{at path midpoint} \qquad (8.3)$$

At λ=2m for, f = 150 MHz and with r = 1 km, Fresnel zone radius becomes

$$b_r = \frac{1}{2}\sqrt{10^3 \times 2} = 23m$$

Accordingly, only if the antenna height is 23m or higher, as shown in Fig.8.3(a) the direct ray would not be obstructed by the ground i.e. Fresnel first half period zone clearance is achieved. At the same time, the ground reflected component will also add upto the direct ray, as the path difference between the direct and reflected rays will be π over and above the phase change of π and of the reflected component at the ground with the antenna height of 23m. It can be shown that for the height h the resultant of direct

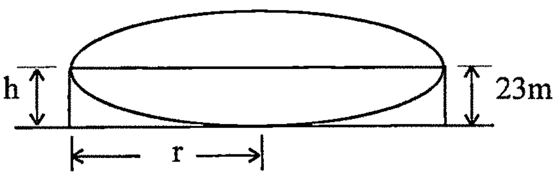

Fig.8.3(a) : Direct ray is no obstructed as the Fresnel hal period zone clearance is achieved

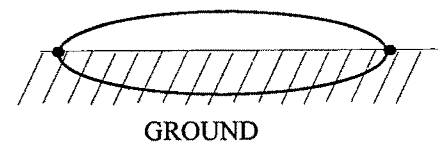

Fig.8.3(b) : Half of the Fresnel half period zone for the direct ray is obstructed by the ground

and reflected ray will add up if

$$h = \frac{1}{2}\sqrt{r\lambda} = 23m \qquad (8.4)$$

for $r = 1000$m and $\lambda = 2$m, h also turns out to be $\frac{1}{2}\sqrt{1000 \times 2} = 23m$

Here, it is important to note that Eqn.(8.3) and Eqn.(8.4) appear to be identical except that in the first one b_r represents the radius of the first Fresnel zone and in the second one h represents the antenna height.

In practice, however, h<<23m and if $h = \lambda = 2$m then almost half of the Fresnel half period zone for the direct ray will be obstructed by the ground as shown in Fig.8.3(b). Under this condition, we may consider ground wave propagation to dominate as the antenna is near the ground level. In that case, the effect of the ground on the radiation resistance of the antenna may also have to be considered, when the antenna is near the ground. Theoretical calculation of the radiation resistance under this condition indicate that the radiation resistance varies with the height of the antenna from the ground in a cyclic manner as shown in Fig.8.4. From the Figure it appears that for $h = \lambda = 2$m at 150 MHz the radiation resistance remains almost unaltered for both the horizontal and vertical polarizations. The effect of ground is, in fact, minimal for heights down to 0.2λ below

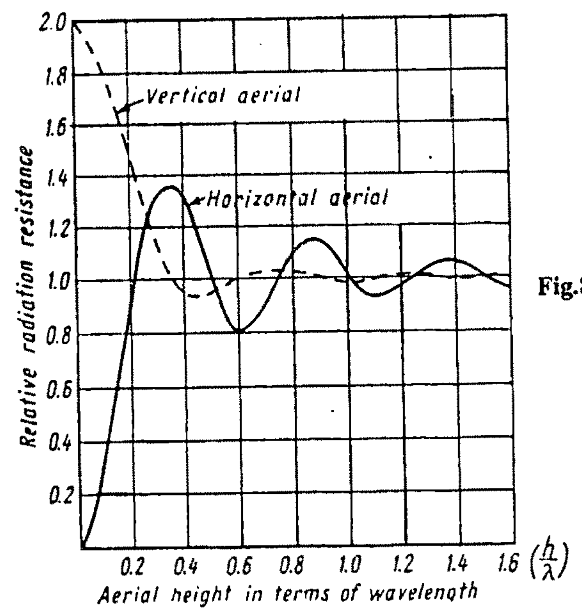

Fig.8.4 Radiation resistance of a vertical and horizontal elementary radiator related to that of free space as a fiunction of radiator height above a perfectly conducting surface.

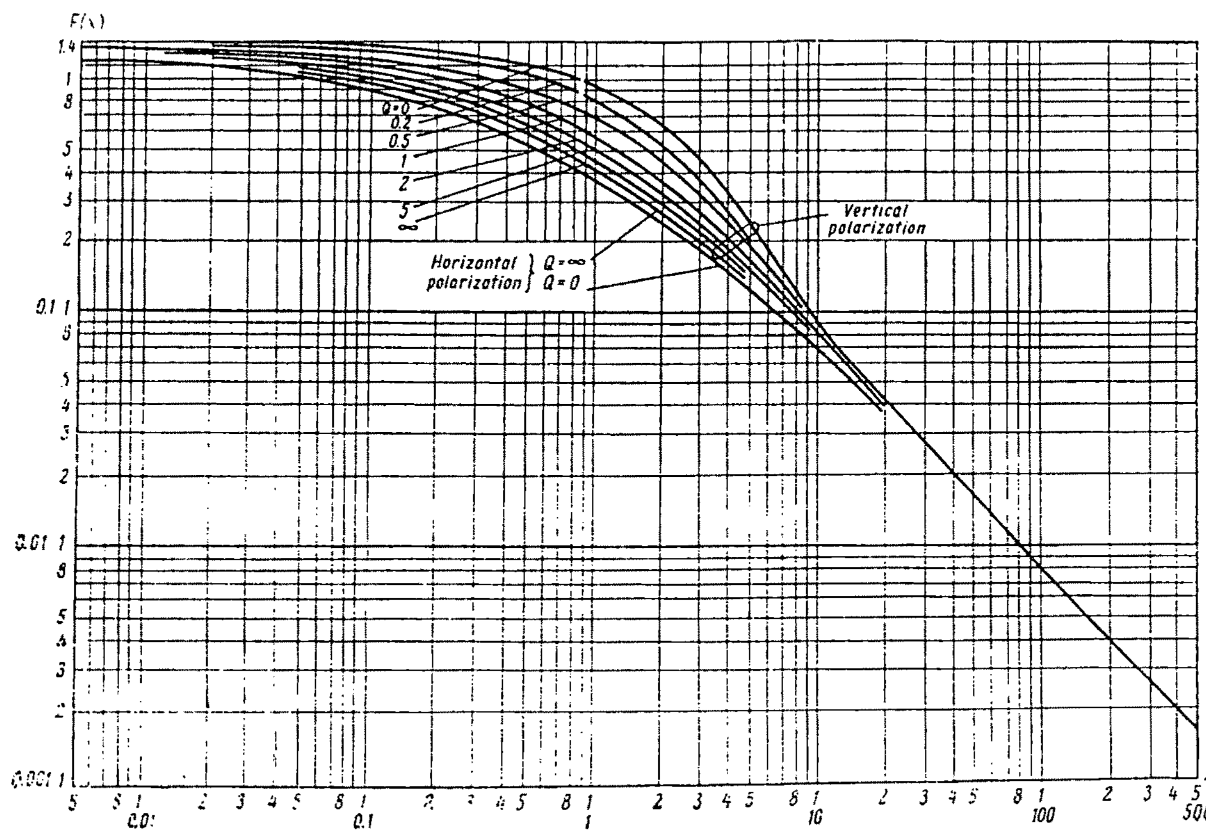

Fig.8.5 Curve for determining the attenuation function F from the calculated value of x

which the radiation resistance increases rapidly with decreasing height for vertical polarization, while it decreases rapidly with decreasing height for horizontal polarisation. Thus, for heights of the antenna height above 0.2λ, we can ignore the effect of ground on the radiation resistance.

The field strength due to ground wave propagation over a partially conducting earth is given by,

$$E_{rms} = \frac{150\sqrt{P_1 G_1}}{r} F \qquad \text{mV/m} \tag{8.5}$$

Where F is the attenuation function. Here, P_1, G_1 and r are expressed in kw, dB and km respectively [*Dolukhanov*, 1971]. For estimation of the attenuation function for the ground wave, the distance r is usually converted firstly to *scale distance* S given by,

$$S = \frac{\lambda(\varepsilon_c')^2}{\pi(\varepsilon_c'-1)} m \tag{8.6}$$

ε_c' being the complex relative permittivity. For practical calculations ordinarily use is made of the magnitude of s given by,

$$s = |S| = \frac{\lambda}{\pi}\left|\frac{(\varepsilon_c')^2}{\varepsilon_c'-1}\right| m \tag{8.7}$$

Secondly, a dimensionless distance parameter called numerical distance x is obtained as given by

$$x = \frac{r}{s} = \frac{r}{\frac{\lambda}{\pi}\left|\frac{(\varepsilon_c')^2}{\varepsilon_c'-1}\right| m} = \frac{r\pi}{\lambda}\left|\frac{\varepsilon_c'-1}{(\varepsilon_c')^2}\right| \tag{8.8}$$

Substituting the expression for complex permittivities as given by

$$\varepsilon_c' = \sqrt{(\varepsilon')^2 + (60\lambda\sigma)^2}$$

From Eqn.(8.8) we get,

$$x = \left(\frac{r\pi}{\lambda}\right) \frac{\sqrt{(\varepsilon'-1)^2 + (60\lambda\sigma)^2}}{(\varepsilon_c')^2 + (60\lambda\sigma)^2} \tag{8.9}$$

It $\varepsilon' >> 1$ then $(\varepsilon'-1) \approx (\varepsilon')^2$ and therefore, the 2nd term on right hand sign of Eqn.(8.8) becomes $\frac{1}{\sqrt{(\varepsilon')^2 + (60\lambda\sigma)^2}}$

Accordingly, the Eqn.(8.9) is changed to

$$x = \left(\frac{r\pi}{\lambda}\right) \frac{1}{\sqrt{(\varepsilon_c')^2 + (60\lambda\sigma)^2}} \tag{8.10}$$

From x we can derive the attenuation function F using the relation [*Dolukhanov*, 1971]

$$F = 1.41 \frac{2 + 0.3x}{2 + x + 0.6x^2} \tag{8.11}$$

for $x > 25$,

$$F \cong \frac{0.707}{x} \tag{8.12}$$

The variation of the attenuation function $F(x)$ with x is plotted as shown in Fig.8.5. The Eqn.(8.12) or the plot of Fig.8.5 can be used to estimate the field strength at the receiving end. Such an estimate of the field strength has been made for a short path LOS link of length 1 Km at 150 MHz (2m) with an antenna height $h = \lambda = 2$m, a transmitter power of 2W and an antenna gain of 1.5. The estimate is given below for two kinds of ground cover : (1) loam soil in the tropics and (2) Antarctic ice surface, having extremely higher and lower conductivities respectively .

Ground wave propagation over loam soil :

For loam soil, $\varepsilon' = 10$ and $\sigma = 0.01$ S/m [*Dolukhanov*, 1971]

Using above equations calculated values of,

Attenuation function, $F = 0.0045$

and Field intensity, $E_{rms} = 0.426$ mV/m (8.13)

Ground wave propagation over Antarctic ice :

For Antarctic ice, $\varepsilon' = 3$ and $\sigma = 0.00001$ S/m [CCIR Report 229-6, 1990]

Using above equations the calculated values of

Attenuation function, $F = 0.00135$

and Field intensity, $E_{rms} = 0.0128$ mV/m (8.14)

From the above estimates of ground wave attenuation indicated in Eqn. (8.13) and Eqn.(8.14) it is evident that the ratio of attenuation of ground wave between loam soil and that to Antarctic ice, is as large as 3.33. It may be noted that at millimeter-waves, the walkie talkie, the usual operating height h=2m, which is orders of magnitude higher; in terms of wavelength. At the millimeter wavelength 2mm (150 GHz) the height of 2m corresponds to 1000λ, whereas at the VHF band at 150 MHz, the antenna height of 2m corresponds only to λ.

In view of the above, the coupling of the antenna to ground for exciting the ground wave would be negligible at millimeterwaves. We are, therefore, left with the direct a ray and the ray reflected from the ground at millimeter waves, similar to that at conventional microwave LOS links, even though the usual height of the walkie talkie is as low as 2m. At the same time, there is also, a possibility of making the antenna beam sharp enough so that the rays within the narrow beam may not touch the ground even at the path midpoint. However, such a sharp beam will be useful only for point to point link at millimeter waves between fixed hutments and not for walkie talkies. A detailed analysis of the performance of millimeterwave commu-nication including point to point fixed path link that of walkie talkies over Antarctica is included in the next section.

8.3.2. Millimeterwave communication :

At millimeterwaves, as the wavelength is short, the height of a handset may be several wavelengths from the icy ground over Antarctica. As a result, there is the possibility of adjusting the height of the handset to a level where the direct and reflected rays may add up in phase to produce a stronger received signal strength. The geometry of the LOS link is shown in Fig.8.6. The received field strength E_r, is given by

$$E_r = \frac{2E_o}{d} Sin \frac{2\pi h_t h_r}{\lambda d} \tag{8.15}$$

where E_o is the free space field at unit distance from the transmitter antenna in the desired direction, λ is the wavelength of the transmission, d is the distance between transmitter and receiver antenna. Here, it is assumed that d>>the heights of the antennas. h_t & h_r are the heights of the transmitter and receiver antennas respectively.

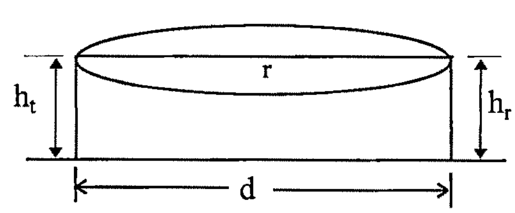

Fig.8.6: The geometry of the LOS link

From Eqn.(8.15), one can plot the field strength as a function of the range or distance between the transmitter and receiver as shown

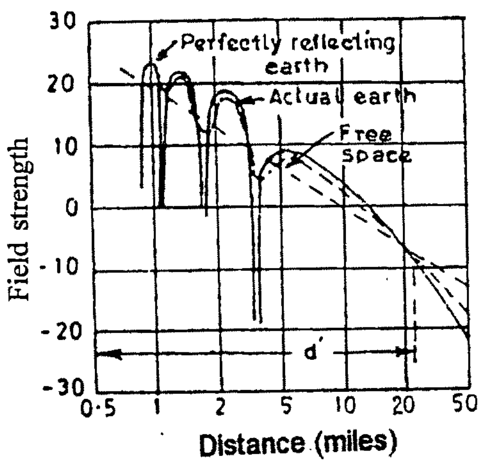

Fig.8.7(a) Field strength as function of distance, flat earth.

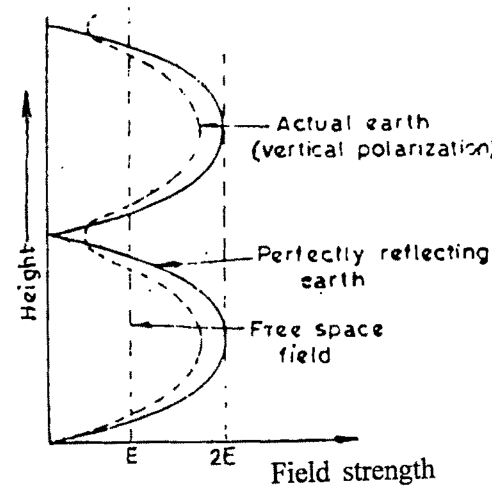

Fig.8.7(b) Field strength as a function of height assuming a flat earth.

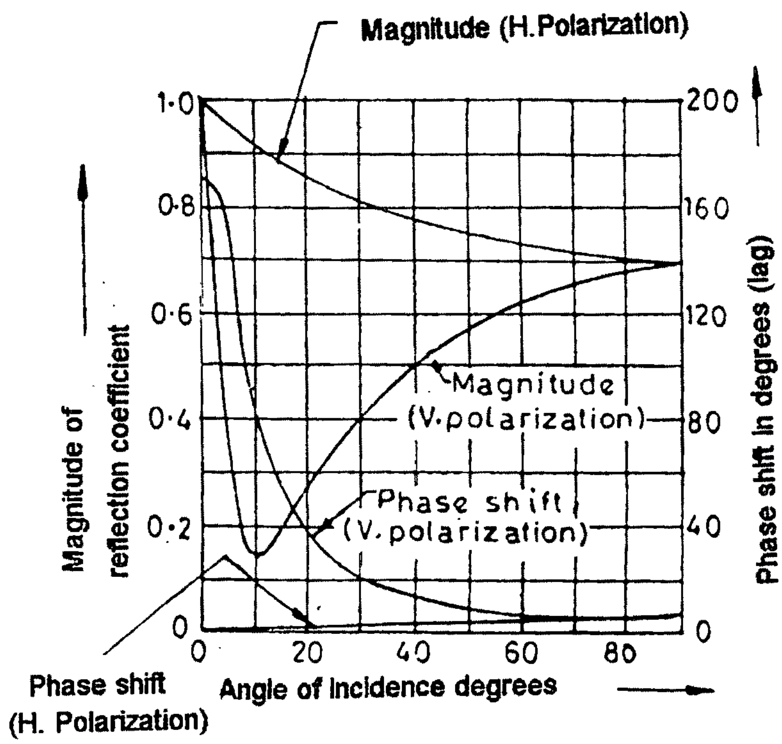

Fig.8.8 Diagram showing curves of reflection and phase shift as a function of angle of incidence for a typical case of imperfect earth.

in Fig.8.7(a) while for a given distance, the field strength varies with height as shown in Fig.8.7(b). The third maximum would occur at 2m which is around the usual height of the walkie talkie. As the rate of change of the resultant field at the receiving end with height around a maximum is zero, one can move in height either sides around the height for maximum field considerably before a sizeable reduction of the resultant field strength become noticeable. It may be mentioned here that for convenience of operation of the walkie talkie the antenna should not have a sharp beam and a horn of suitably small mouth area may be chosen to attain a desired broad beamwidth.

It may also be mentioned here that in the above derivation of the resultant field at the receiving end presumes that the angle of incidence for the reflected ray is very nearly glancing. If the range of the link is reduced to a stage where this angle can no longer be glancing, we have got to take into account of the dependence of ground reflectivity on the angle of incidence as shown in Fig.8.8 from which it appears that for vertical polarization the reflection coefficient drops down to a minimum value of 0.15 for an angle of incidence around 10^0, while for horizontal polarization the coefficient is 0.9 for the same angle of incidence 10^0. This suggests that for a fixed path LOS link if the range or the height of the antenna is such that the angle of incidence of the reflected component is around 10^0 then the use of vertical polarization will reduce drastically the interference due to reflected component.

8.4. Selection of link operating frequencies :

At frequencies above 10 GHz, electromagnetic radiation starts to interact with various atmospheric gases, oxygen and water vapour in particular, resulting in attenuation of the signal levels. The designer of mm-wave systems, therefore, requires to predict this attenuation to determine adequate fade margin, to ensure a predetermined level of reliability under a wide range of weather conditions. Because oxygen concentration is same all over the world, it is easy to predict, but, water vapour concentration in the atmosphere changes with time and location. So, a detailed study on the water vapour variation should be carried out before coming out with a final specification of the mm-wave system for Antarctica.

In order to get an idea of how much fade margin should be taken in the design of mm-wave system for use in Antarctica, the 22.235 GHz radiometric data have been used. A 22.235 GHz radiometer was taken to Antarctica for water vapour measurement. The details of measurement and techniques involved are explained in Chapter 2 and Chapter 4 respectively. The measurement was carried out during polar summer which is crucial considering the fact that water vapour remains at its maximum value during that period. From 22.235 GHz brightness temperature value, zenith opacity was calculated from 10 GHz to 300 GHz using *Liebe* (1989) model.

8.4.1. Operating frequency for earth-EES link :

The frequency (GHz) versus zenith opacity (dB) graph, Fig.8.9, clearly shows a very low attenuation trend at the window frequencies as compared to other locations in India as discussed in Chapter 4. In addition to this, a significant shift in window frequency near 94 GHz is observed in Fig.8.9. As pointed out in Chapter 6 that communication window for vertical (surface to satellite) and horizontal (surface to surface) must be different, therefore, attenuation coefficients (dB/km) were calculated for 10-300 GHz with surface meteorological parameters to find out correct window frequency. The maximum and minimum attenuation during the month Dec.1991 to Mar.1992 is given in the Table-8.1. Zenith opacity values for a range of frequencies were calculated out of which 28-32 and 40-49 bands were found to be suitable for uplink and down-link. The zenith opacity values at two extreme humidity conditions show that a frequency of 44 GHz for the uplink, 30 GHz for the down-link may be suitable for EES-Antarctica link. The low water vapour content in Antarctica allows the millimeter bands al 30 and 40 GHz to be used for Ground-EES link with the small atmospheric attenuation as indicated in Table 8.1.

Table 8.1 : Selection of working frequency for ground to satellite communication considering two extreme humidity conditions

LOS Surface to EES communication				
Mode of comm.	Usable freq. range (GHz)	Selected frequency (GHz)	Zenith Opacity (dB)	
			at min. humidity (1.31 gm/m^3)	at max. humidity (6.21 gm/m^3)
Uplink	28 - 32	30	0.0355	0.0914
Downlink	40 - 49	44	0.1075	0.1767

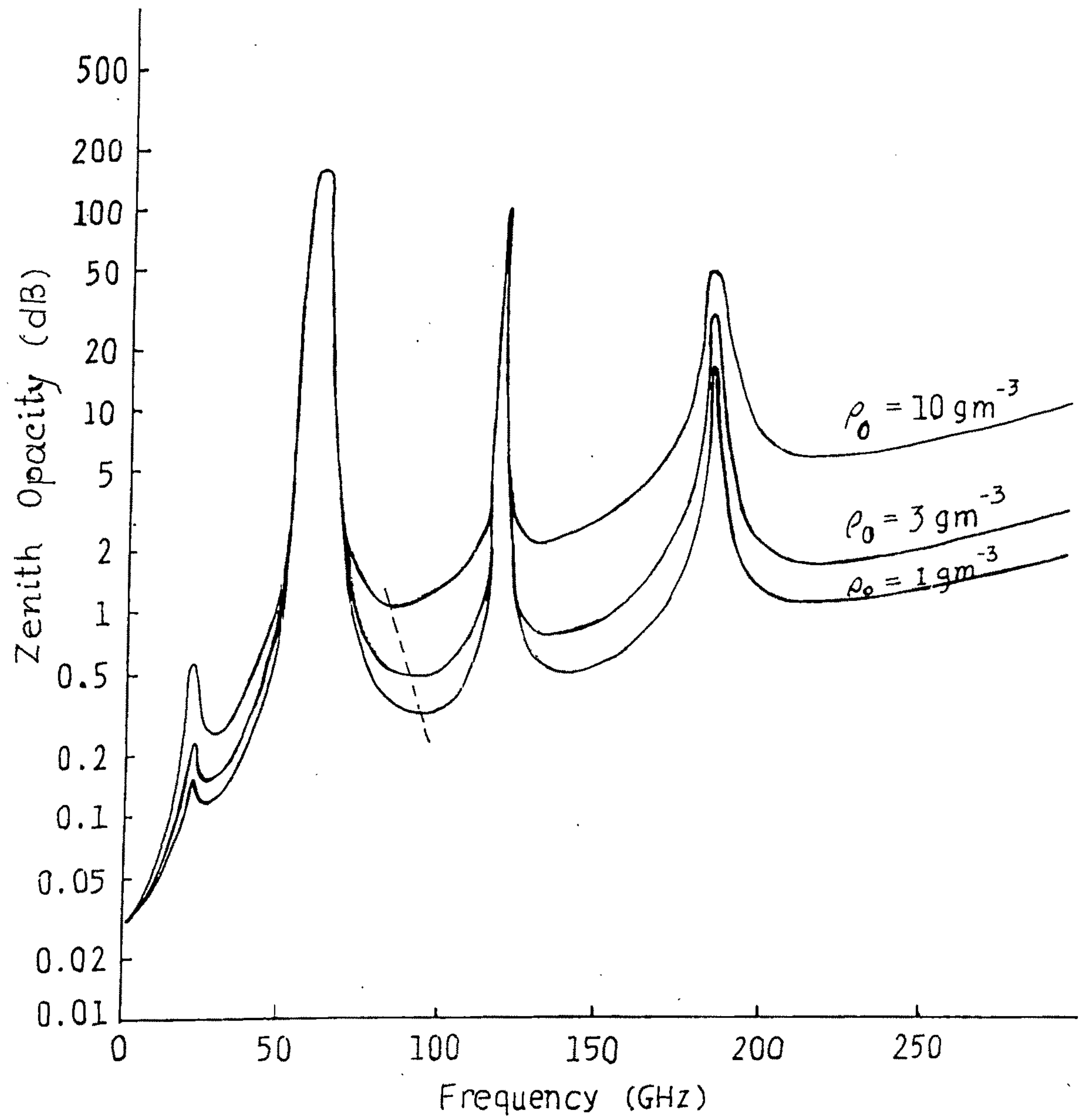

Fig.8.9 : A significant shift in 94 GHz window frequency is shown for different surface water vapour densities. This is confirmed from the minimum zenith opacity point shifted from 94 GHz point.

The use of mm-waves also allows light weight small dish antennas to be employed so that fast angular tracking of antennas may be feasible. If onboard tracking becomes difficult due to limitation of size and weight of tracking systems, a wide-beam antenna may be used with the onboard transmitter power increased suitably. Such increase of onboard transmitter power is also having limitation since onboard source of primary electrical power based on solar cell is limited. However, for the Ground - EES link as the LOS path length is not large the normally available onboard transmitter power may be good enough to be radiated by a broadbeam antenna.

8.4.2. Operating frequency for EES-GSO link :

As the water vapour density at EES height and above is negligible and that altitude of EES is well above the troposphere, the attenuation due to tropospheric weather phenomena is absent. As a result tropospheric window frequency will not be shifted but will remain around 35 GHz and further it will become much broader so that even at 22 GHz the attenuation rate is low and acceptable. A good choice of EES-GSO link may, therefore, be 22 GHz for uplink and 19 GHz for downlink. In that case the onboard transmitter at GSO for the existing 19 GHz downlink may be exploited for obtaining the GSO-EES downlink transmission. At the same time, the 22 GHz uplink to GSO will have negligible leakage to the onboard 44 GHz receiving system for Ground-EES link. It may be mentioned here that in case of GSO-Ground global communication link. 11 and 27 GHz for downlink and 14 and 19 GHz for the up-link have already been allocated as suitable frequencies (*Jansky*, 1983), besides the conventional 6/4 GHz link. The link between

GSO and the user at non-polar latitudes should, however be operated in the Ku band (14/11 GHz) available which are the best compromise bands for communication to tropical regions, where rain attenuation is a major problem. For exceptionally rainy regions like that in Cherapunji in Assam of Eastern India, the conventional 6/4 GHz would be better, while for temperate regions with lower rain rates the 27/19 GHz may be exploited.

8.4.3. operating frequency for surface to surface link :

For surface to surface communication over the Antarctica, the optimum window frequency is found to vary between 79 to 90 GHz at various times of the year and corresponding attenuation values are given in Table 8.2. The attenuation values at two extreme climatic conditions show that 85 GHz would be the best compromise operating frequency for surface to surface communication at the polar regions. Another plot, showing frequency(GHz) versus surface attenuation coefficient (dB/km)was drawn in Fig.8.10. As seen in the graph, at 1.31 gm/m^3 surface water vapour density window exists between 88 to 93 GHz and for 6.21 gm/m^3 surface water vapour density, the range 76-82 GHz may considered as window. In comparison between the two graphs and values given in Table 8.2, the 85 GHz would be most suitable window frequency at Antarctica for surface to surface communication. However, for transponders operation the transmitter and receiver frequencies should be separated by 3 GHz for avoiding the leakage of transmitter power to the local receiver. Accordingly the two frequencies for forward and backward LOS links could be 85 and 82 GHz respectively.

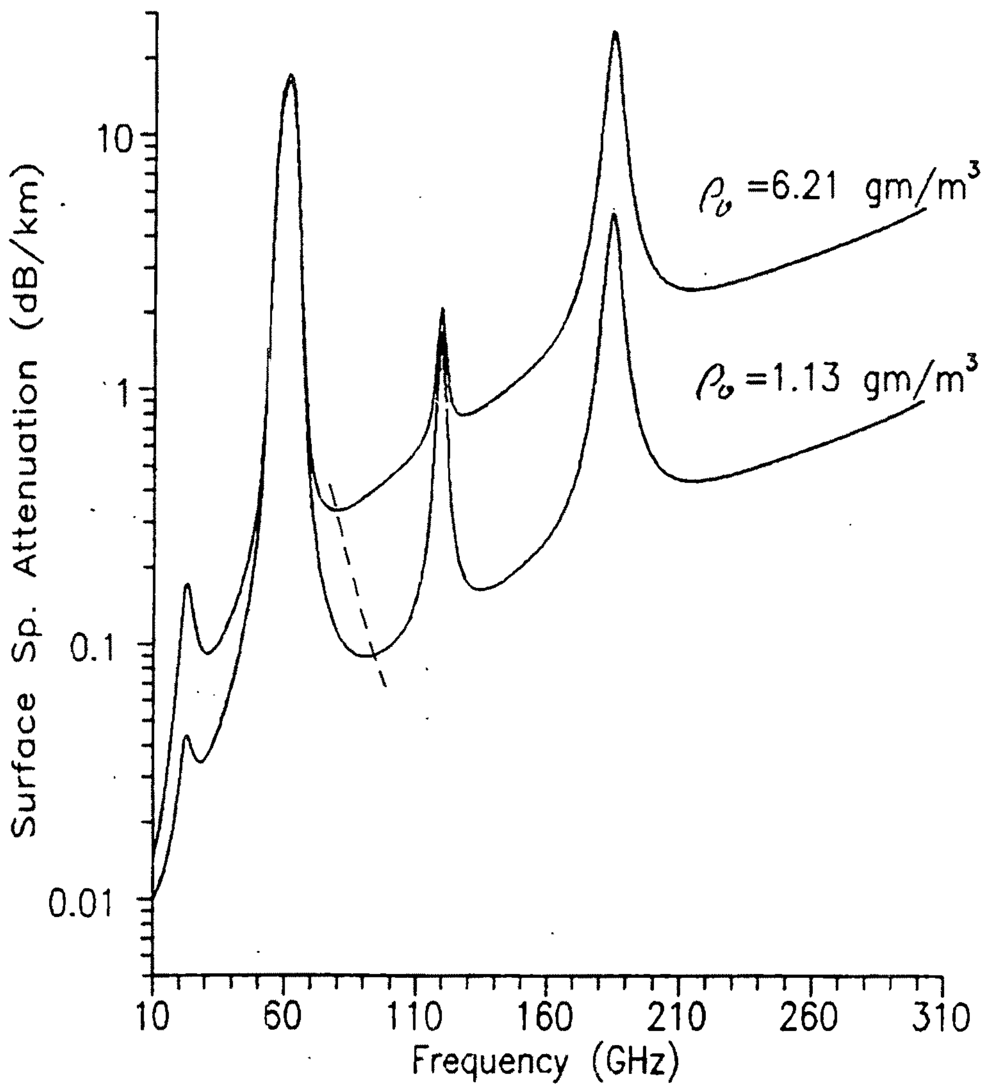

Fig.8.10: The frequency(GHz) versus surface attenuation coefficient (dB/km) graph at 1.31 g/m^3 and 6.21 g/m^3 shows the existence of window frequency between 88-93 and 76-82 respectively.

Table 8.2 : Selection of working frequency for surface to surface communication considering two extreme humidity conditions

LOS Surface to Surface Communication					
Surface water vapour density (gm/m^3)	Window range (GHz)	Window centre		Selected window	
		Frequency (GHz)	Attenuation (dB/km)	Frequency (GHz)	Attenuation (dB/km)
1.31	88 - 93	90	0.0889	85	0.0926
6.21	76 - 82	79	0.3325	85	0.3494

8.5. System configuration :

8.5.1. Configuration of Antarctica-EES-GSO Link :

The outstanding problems of a mobile surface communication over Antarctica, could be solved by moving up to the millimeter wave band around 85 GHz, while ground-EES and EES-GSO links are also possible at millimeter wave with 44/30 and 35/19 GHz links respectively as indicated in the preceding sections. However, at millimetre waves the generation of the required transmitter power by solid state devices was beyond reach until *Hughes* (1986) announced a 25 watt CW source at 44 GHz capable of establishing a link between Antarctica and orbiting relay satellites. For a mobile earth station with an uplink at 44 GHz, communication with an orbiting satellite is, in fact, possible with a meagre power of 15 watts.

A block diagram of the millimeter wave satellite link at 44/30 GHz between the EES and earth terminal at Antarctica is shown in Fig.8.11. The use of millimeter wave allows a smaller antenna diameter to facilitate mobile operation, in addition to providing for a wide communication bandwidth of a few GHz available at millimeterwaves. A 20 mW GUNN PLO at 42.5 GHz is upconverted to obtain 44 GHz from a synthesised local oscillator at 1.5 GHz.

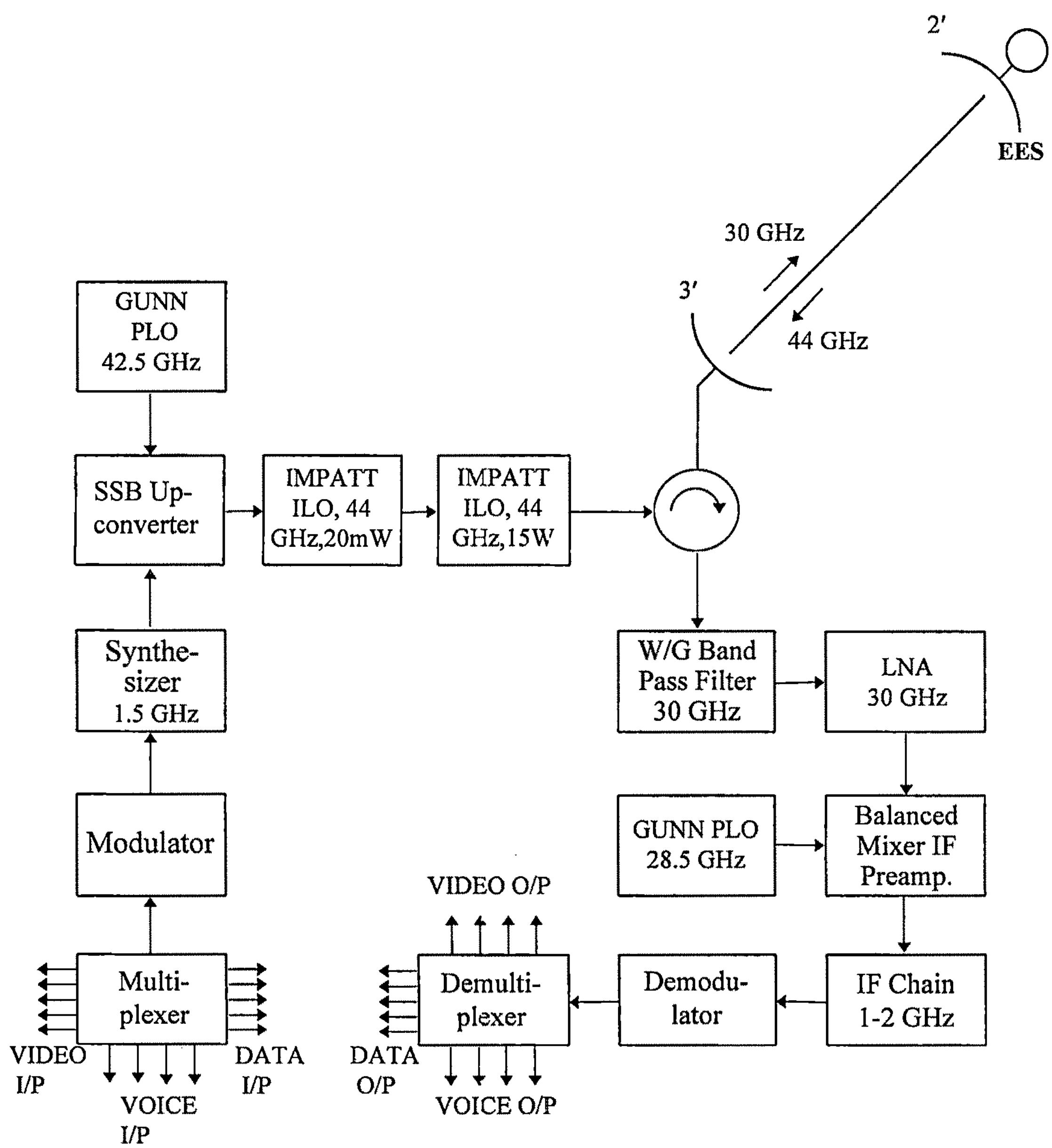

Fig.8.11 : Block diagram of mm-wave satellite link at 40/33 GHz between EES and Antarctic earth terminal

8.5.2. Configuration of EES-GSO link :

The onboard transmitter for EES operating at 22 GHz, an output power of 200W is produced by TWT. Such high powered TWT has, in fact, been developed in Japan for satellite HDTV broadcasting. The remaining part of the transmitter and that of the receiver are similar to that of the 40/30 GHz. Transponder for EES shown in Fig.8.12, except that the operating frequencies are 22 GHz for up-link and 19 GHz for down-link, which is frequency modulated by the baseband communication signal. On the receiving side the transponder for incoming signal at 30 GHz from the ground is filtered, amplified by an LNA before converting it down to 1.5 GHz IF by a local oscillator based on GUNN PLO at 28.5 GHz..

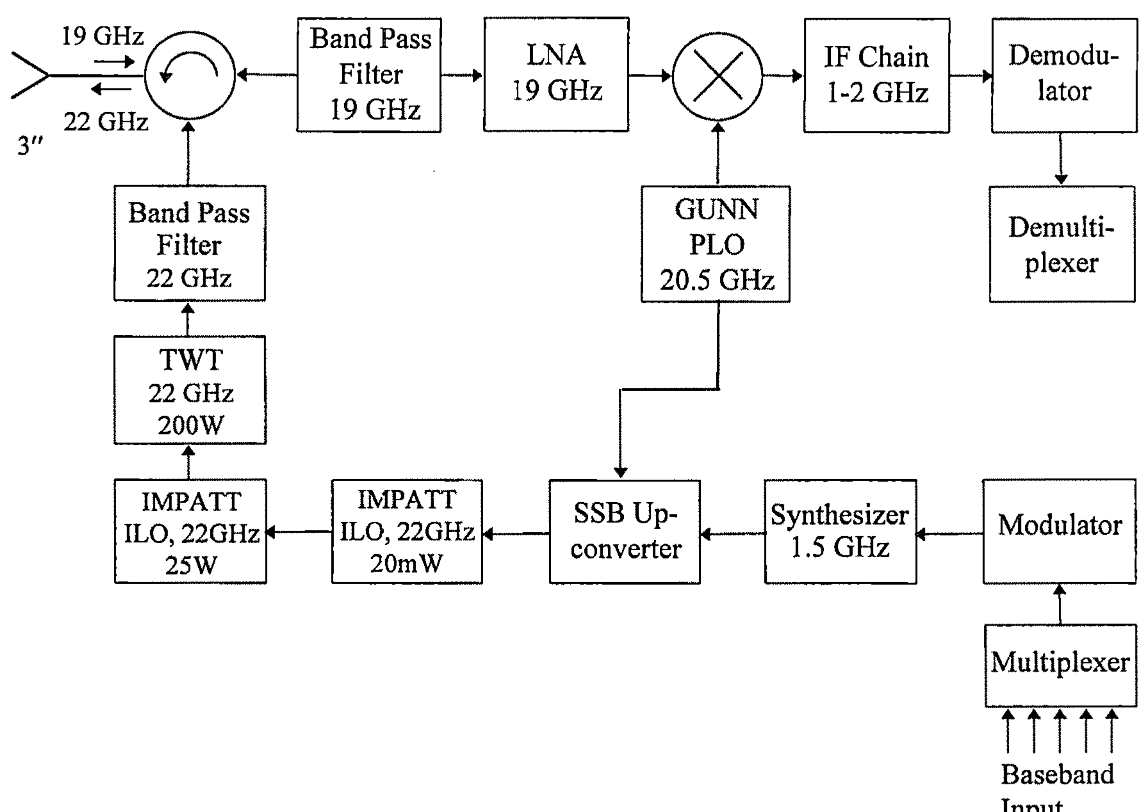

Fig.8.12 Block diagram of EES-GSO link

8.5.3. Configuration of short range surface to surface communication :

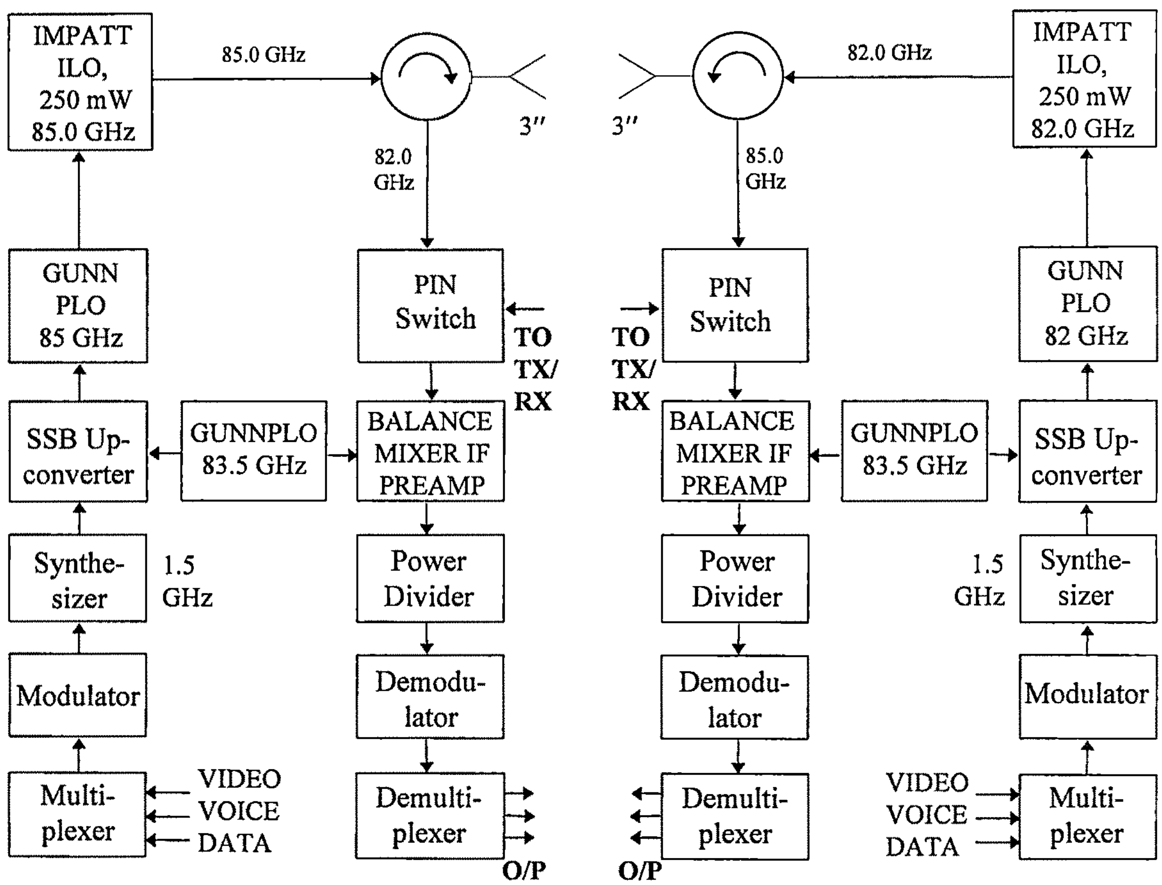

Fig.8.13 Block diagram of mm-wave ground to ground LOS link at 85 GHz for audio, video and data communication

Fig.8.13 illustrates the block diagram of a millimeter wave LOS link over Antarctica to cover distances between hutment to hutment (=6 km) and also between hutment to ship (=15 km). The configuration is similar to that for EES transponder at 22/19 GHz except that the operating frequencies are 85/82 GHz. It is important to mention that the LOS link operating at the atmospheric window around 85/82 GHz will acquire very light weight terminal equipment with only even horn lens antenna of horn mouth diameter 3 to 4 inches which will be capable of establishing a link of about 15 km path. The detailed configuration of the systems have been described in Table-8.3. It may be mentioned here that the height of the horn lens antennas at both the transmitter and receiver ends should be large enough to avoid reflection of the sharp beam from the ground. Also, the lens geometry is adjusted to produce a distribution of millimeterwave illumination across the mouth of horn, so that the side lobe level may be at a minimum, down to about -30 dB or lower.

8.6. Discussions :

The results presented so far revealed that Antarctica is, an ideal location for communication at millimeter wave lengths in comparison to the widely varying climatic region like Calcutta. It is not only due to the small and rugged equipment requiring low voltage supply but more so because of an excellent humidity free Antarctic atmosphere which is an ideal environment for millimeterwave propagation. Moreover, the rain events which are worst offender of mm-wave propagation are sparse over Antarctica in contrast to that over Calcutta. Also, the prevailing snow storms over Antarctica pours in with extremely dry type snow, with a sandy texture, occasionally at a rate of 2 mm/min offering extremely low attenuation of about 0.05 dB/km (*Curie and Brown*, 1987). Keeping all these facts in view, it is suggested that a simple 85/82 GHz link is good enough for local communication on the surface for its minimal attenuation, while 44/30 GHz satellite link with EES (1000 km orbit) can give wide band link to the home-base, supported by the EES-GSO link at 22/19 GHz.

Table 8.3 : Millimeterwave link parameters over Antarctica

Mm-wave link parameters	Dis-tance (km)	Antenna dia. (inch). With 55% gain (dB)	Freq. (Ghz)	T_x Power (watt)	Free Path Loss (dB)	Receiver characteristics at300K			C/N ratio approx. (dB)
						Band-width (MHz)	Noise Figure (dB)	Sensiti-vity (Watt)	
Hutment to hutment	6	4, 37.4 4, 37.4	85	0.25	147	40	4.5	$4.6x10^{-13}$	45
Ship to hutment	15	12, 46.9 12, 46.9	85	0.25	156	40	4.5	$4.6x10^{-13}$	56
ERT*to EES# up-link	13,756	36, 49.9 36, 46.4	40	15	208	40	4.5	$4.6x10^{-13}$	24
EES to ERT down-link	13,756	24, 43.0 36, 46.5	30	15	205	40	4.5	$4.6x10^{-13}$	20
EES-GSO♣	40,000	36, 48.7 24, 45.1	35	15	206	40	4.5	$4.6x10^{-13}$	35
GSO-EES	40,000	24,39.8 36,43.4	19	15	201	40	4.5	$4.6x10^{-13}$	35

* Earth Receiving Terminal   # Earth Exploration satellite   ♣ Geostationary Orbital satellite

It may be mentioned here that, widespread utilisation of millimetric wavelengths for communication systems will only be a reality, if component and device costs are reduced. Currently millimetric technology is still relatively expensive compared to that at lower frequencies. Fortunately circuit integration, at substrate level, has come up recently also at millimeterwaves upto 94 GHz and commercially available sub-systems and systems in integrated form through MMIC technology at millimeter-waves have come up. As a result, cost of millimeter wave systems including the transponder may no longer be a barrier for the application of millimeter-waves in Antarctic communication systems.