Mm Waves Role in Satellite Communication

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Abstract: *Millimeter Wave satellite communications are discussed with only modest site separation and switched diversity .Various aspects of MM Wave communication link at 35 GHz ,60 GHz and 94 Ghz frequencies for satellite applications are discussed in the paper. Link calculations are carried out and possible hardware configurations are sketched out briefly in respect of Ground Satellite and Inter Satellite Communications Links*
Key word: *Satellite communication, Satellite Spacing, Millimeter wave communication*

I. Introduction

The frequency band of Millimeter Wave (MM Wave) in Electromagnetic spectrum is 30-300 GHz and is sometimes called the Extremely High Frequency (EHF) range. Apart from Radar system, communication system is another important application of MM Waves which proved better than Microwaves/optics in certain features. Certain characteristics of the earth's atmosphere pose both problems and solutions for millimeter wave applications. For example, at 60 GHz (5 mm or 0.2 inches wavelength) oxygen molecules will interact with electromagnetic radiation and absorb the energy. This means 60 GHz is not a good frequency for use in long-range radar or communications, because the oxygen absorbs the electromagnetic radiation—and the signal. On the other hand, since the 60 GHz signal does not travel far before it loses all its energy, this frequency comes in handy for secure short-range communications, such as local wireless area networks used for portable computers, where it is important that hackers do not tap into the data stream. Another use for 60 GHz technology is communications between satellites (called cross-linking) in high earth orbit. Since there is almost no oxygen in space at the geosynchronous altitudes of 43,000 km or 26,000 miles), 60 GHz works just fine for communication between satellites

II. Satellite Communication

Satellite Communication in telecommunications by use of artificial satellites to provide communication links between various points on Earth. Satellite communications play a vital role in the global telecommunications system. Approximately 2,000 artificial satellites orbiting Earth relay analog and digital signals carrying voice, video, and data to and from one or many locations worldwide. A typical satellite link involves the transmission or uplinking of a signal from an Earth station to a satellite. The satellite then receives and amplifies the signal and retransmits it back to Earth, where it is received and reamplified by Earth stations and terminals. Satellite receivers on the ground include direct-to-home (DTH) satellite equipment, mobile reception equipment in aircraft, satellite telephones, and handheld devices. . Satellites located in this Geostationary Orbit are available to all Earth Stations within their shadow, 100% of the time. The prime advantage of Satellite Communication over terrestrial communication is greatly exceeding coverage area. The maximum area that can be covered by a Geostationary Satellite is around 33% of the earth's surface. That means the communication needs of a country like India can be met by a Communication Satellite launched and located in the Geostationary Orbit.

The main disadvantage with Satellite Communication (Geostationary) is the time delay of around 260 milliseconds. In the case of continuous Television transmissions this factor does not matter. But in the case of control signals that move back and forth between a computer's CPU and its peripheral devices this factor is critical. Here, the computer systems that use Satellite Communication system should be carefully designed and realized to include/absorb this type of time delay.

The distance (d) between a particular location on the earth's surface and a Geostationary Satellite depends on Latitude (θ) and Longitude (Φ) of the location and longitude (Φ) of the satellite. This distance can be estimated in (i.e., (1) reads as "equation 1")

When both θ & Φ are equal to 0º, (i.e., on earth's equator) the Geostationary Satellite Orbit is at a height of around 35,800 Km. The maximum height is around 42,650 Km when both θ & Φ are equal 90º.

The shadow of a Satellite includes all the Earth Stations that have a LOS (Line of Sight) path to the Satellite and within the Radiation Patterns of the Antennas located onboard the Satellites. These advantages of this

application outweigh drawbacks like signal loss and time delay caused due to the great distance of satellite from earth.

Irrespective of the MM Wave band allocations for satellite links across the world, the estimations are carried out for various RF parameters.

II.1 Mmwaves In Satellite Communications

MM Wave Communication Satellites can be employed as repeaters. In this case, they receive signals in one frequency band (up link 36 GHz or 96 GHz or 62 GHz) and re-transmit the signals in another frequency band (down link 34 GHz or 94 GHz or 60 GHz) like a conventional transponder (Fig.5). These satellites can use 10 W Low Power Amplifiers at 34 GHz/36 GHz or 94 GHz/96 GHz or 60 GHz/62 GHz. The requirement of using Low Power of this order is to have optimal use / conservation of the solar energy available on- board the satellite. To compensate for the lower powers, the satellites employ higher gain/highly directional antennas and Low Noise Amplifier based receivers. The difference of about 1-2 GHz in the Down Link/Uplink frequency is to ensure that no signal interference takes place during the communication phase. Here also the communication links employ digital techniques.

A Ground Based Satellite Receiver sees a 'COLD' Noise Source (RF) when looking at Satellite and hence it is practically possible for the Satellite to give small amount of output power where as Ground Based/Earth Station Receiver still maintains a good Signal to Noise Ratio. Thus these Satellites which are used as means of relaying information results in the communication of different types (Telephone, Fax, Radio, TV, Data) and Navigation, Weather Broadcasting and Defense applications (Surveillance, Reconnaissance, Aircraft/Missile Detection, Guidance and Control).Space Loss (Path Loss) – Satcom: This parameter is indicated by $(4 \pi d/\lambda)^2$ where λ is wavelength of the MM Wave carrier signal and 'd' is the distance between Geostationary Orbit and the Earth station. The value is nothing but $– [97 + 20 \log f + 20 \log d]$ where 'f' is the carrier frequency in GHz and d is distance in Miles.

II.2 Satellite Spacing – Geostationary Orbit

The Geo Orbit exists as a circle around the earth at a height of around 35,800 Km. A good number of Satellites can be placed anywhere in this orbit. Longitude is used to specify a particular location in this orbit, because the Latitude for all the Geo Satellites is 0º.

The number of Satellites that can be placed in this orbit is determined by the minimum spacing between the orbits. Again this minimum spacing value is limited/controlled by the capability of earth station receivers to distinguish signals from any two adjacent satellites. When these two satellites use two different down link frequencies these can be placed very close to earth other because there will be no RF signal interference.

But when once the two satellites employ same up/down link frequencies, to avoid and minimize the signal interference, they should be located with a spatial elevation difference of 4º. For Geo orbits this corresponds to a distance of about 2950 Km between the two adjacent satellites.

For the uplink frequency of 36 GHz for the transponder indicated in Fig.5 (a), the Power (RF) reaching the Receiver (P_R) of the satellite transponder (Geostationary) is estimated in equation 2. (G_R = Gain of Rx Antenna on Satellite)

With these values, the P_R turns out to be -81 dBm. This signal is amplified by the first stage LNA with a gain of around 30 dB which gives an RF Power output of -51 dBm to the receiver input. The signal of 36 GHz is down converted to a frequency of 34 GHz.

This signal is fed to a high power amplifier, with 60 dBm power output and subsequently to the Transmit Antenna of Transponder (Gain of 30 dB). (Fig.5b) In turn, the power reaching Earth Station Receiver after Antenna with a gain of 50 dB turns out to be -71 dBm. This will be again suitably amplified and brought down to an appropriate IF to get the received communication signals processed.

Because Inter Satellite Links do not face the problem of atmospheric attenuation, 94 GHz / 60 GHz / 36 GHz carriers can be used keeping in view of the smaller size of the system components and less power requirement of the communication system. Fig.6 indicates simplex Inter Satellite Communication system at 94 GHz/60 GHz/36 GHz. A typical calculation for the above mentioned system at 60 GHz, 36 GHz and 94 GHz are carried out as given below

III.   Figures and Tables

Equation 1
$d^2 = X^2 + R^2 – 2 Rx \cos \theta \cos \Phi$
Where   R = 6378 Km, earth's Radius
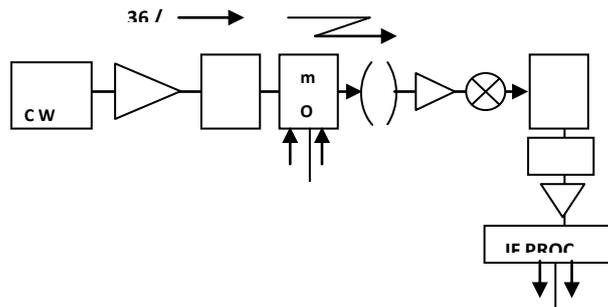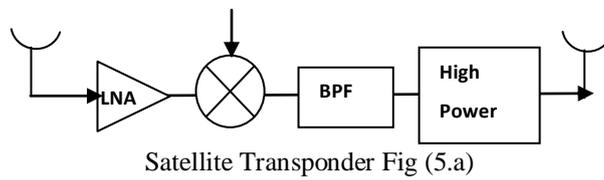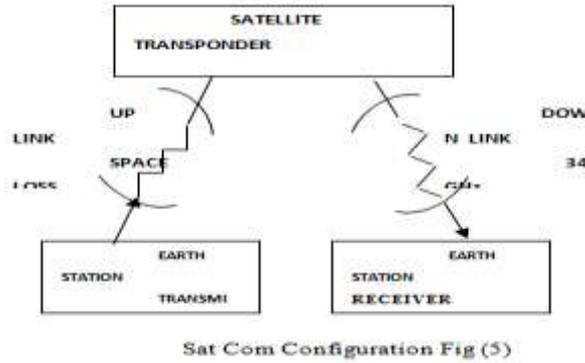X = 42178 Km = The distance from centre of earth to satellite.

Equation 2

$P_R = P_t + G_t -$ Space loss $-$ Plumbing loss of Transmitter (L_T)
$+ G_R -$ Plumbing Loss of Receiver (L_R)

In this case

$P_t = 70$ dBm
$G_t = 40$ dB
$G_R = 30$ dB
$L_R = L_T = 3$ dB
$S_L = 215$ dB

IV. Figures and Tables

Sat Com Configuration Fig (5)

Satellite Transponder Fig (5.a)

Inter Satellite Communication System Fig (5.b)

Parameter	6GHz	636 GHz	94 GHz
Inter Satellite Range (S_R)	2,950Km	2,950 Km	2,950 Km
Transmitter Power (Tx)	1.0 W	100 W	10 W
Atmospheric Loss (A_L)	0	0	0
DataStream Capability	100-1000 KBPS	100-1000 KBPS	100-1000 KBPS
Transmitter Plumbing Loss (T_L)	4 dB	4 dB	4 dB

Path Loss (P_L)	198 dB	194 dB	202 dB
Rx/Tx/Antenna Gain	50 dB	40 dB	50 dB
Receiver Plumbing Loss (R_L)	4 dB	4 dB	4 dB
Power ReachingRx Input	-76 dBm	-72 dBm	-70 dBm

Fig (6)

V.   Conclusion

At MM Waves, Communication links (Ground to Satellite and Inter Satellite) of different types can be realized.

Acknowledgement

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