Indian Institute of Information Technology, Allahabad

Electronics and Communication Engineering Department

Course Name: Radar & Satellite Communication

Experiment-8

Aim - To Measure the C/N ratio.

C/N

OBJECTIVE:

To measure the C/N ratio.

EQUIPMENT REQUIRED:

- Satellite transmitter, satellite receiver and satellite link emulator
- Pair of Yagi antennas and RHCP & LHCP axial mode helix antennas, Dish Antennas, Patch antennas
- Antenna stands with connecting cables, Mic, PC monitor(from Lab) , Video to VGA converter card provided, Camera, Function generator (from lab), CRO X 2 (from lab), spectrum analyzer (from lab)

THEORY :

Carrier-to-noise ratio

For the Ku and Ka bands the system carrier-to-noise (C/N) ratio is given by:

C/N = EIRP - Lfr+ G/T usable -10 log (kB) -Arain -Aatm (dB)

where : EIRP = the equivalent isotropic radiated power from the satellite at the site location (dBW)
Lfr = free space path loss on the earth to satellite path (dB)
G/T usable = minimum degraded value of the system figure of merit (dB/K)
k = Boltzmann's constant (1.38×10^{-23} J/K)
B = receiver's pre-detection intermediate frequency (IF) bandwidth (Hz)
Aatm = gaseous attenuation due to atmospheric absorption (dB)
Arain = rain attenuation for a given percentage of the time (dB).

Note: (a) Arain & Aatm can be omitted for operation frequencies of <8 GHz; and
(b) for a 'clear-sky' calculation omit the Arain term and substitute the nominal figure of merit, G/T(nominal), for G/T(usable).

Antenna noise

Any signal received is combined with an element of noise, which degrades the overall performance:
Signal = wanted signal + noise

Obviously, the noise component must be kept as small as possible, taking into account cost and available technology. Noise can come from many sources and is produced by the thermal agitation of atoms and molecules above absolute zero (-273°C or 0 K; note that the degree sign is not used on the kelvin scale). This is why noise is said to have an equivalent noise temperature. The noise temperature of the earth is normally standardized at 290 K (17°C). There are three main sources of noise in the environment:

1.Extraterrestrial noise sources- This is wide bandwidth radiation caused by the energy conversion in stars and the residual back-ground radiation of the 'big bang'. This tends to taper off at 1 GHz and settles to that of the residual background noise alone which is taken as 2.7 K. Above 2 GHz, there are only a few isolated points of very strong non-thermal noise, principally from Cygnus A, Cygnus X, Cassiopeia A and the Crab nebula. There is also a narrow band of increased noise from the Milky Way. The Sun is an enormous source of noise at around 10,000 K at 12GHz and the Moon at about 200 K. **This noise enters the antenna mainly via the main lobe.**

2. Man-made noise- This noise emanates from microwave pollution due to man's electrical activities and principally **enters the antenna via the side lobes.**

3. Ground noise- In the long term, this is the major component of noise incident on the antenna aperture, and depends mainly on the antenna diameter, antenna depth, and elevation setting. The smaller the diameter of the dish the wider and more spread out will be the side lobes, so more noise will enter from the warm earth. The noise temperature also increases as the elevation angle decreases, since lower elevation settings will pick up more ground noise due to side lobes intercepting the ground (diffraction effects at the antenna rim). This may be reduced by various methods of feed illumination. The design of the antenna itself also plays a part. A deep dish picks up less ground noise at lower elevations than do shallow ones, also prime focus mounted head units will add to noise since it is 'seen' at the same temperature as the Earth. Inclining the head unit away from the earth and towards the cool sky as happens in the case of an offset focus design can also improve things. This practice tends to counteract the negative effects of increased beamwidth for small antennas set at low elevation angles.

Noise and its effects

Any body, above the temperature of 0 K or -273°C has an inherent noise temperature. Only at absolute zero temperature does all molecular movement or agitation cease. At higher temperatures molecular activity causes the release of wave packets at a wide range of frequencies some of which will be within the required bandwidth for satellite reception. The warmer the body the higher the equivalent noise temperature it will have, resulting in an increase in noise density over the entire spectrum of frequencies. The warm earth has quite a high noise temperature of about 290 K and consequently rain, originated from earth, has a similar value. **The characteristic appearance of noise on FM video pictures can be either black or bright white tear drop or comet shaped blobs (sparklies) that appear at random on the screen.** It is subjectively far more annoying than the corresponding snowy appearance of noise on terrestrial AM TV pictures. Video cassette recorder pictures, also frequency modulated, display annoying sparklies as a result of worn/dirty heads or faulty head amplifiers. Only relatively small amounts of FM noise can be tolerated.

Free space path loss

As the radiated signal of a transponder travels towards earth it loses power by spreading over an increasingly wide area thus diluting the signal strength. This effect is known as the free space path loss and the greater the distance the receiving site from the satellite the more it increases. Contributory factors include absorption of microwaves by gases and moisture in the atmosphere. The power density of signals, measured in watts per square meter, finally arriving at earth are extremely weak.

Rain attenuation

One of the major problems with satellite reception is rain, and to a lesser extent snow and hail. The weak incoming microwave signals are absorbed by rain and moisture, and severe rainstorms occurring in thunder conditions can reduce signals by as much as 10 dB (reduction by a factor of 10). Not many installations can cope with this order of signal reduction and the picture may be momentarily lost. Even quite moderate rainfall can reduce signals by 2 to 3 dB which is enough to give noisy reception on some receivers. Another problem associated with rain is an increase in noise due to its inherent noise temperature, which is similar to that of the earth. **In heavy rain depolarization of the signal can also occur resulting in interference from signals of the opposite polarization but same frequency.** This effect is more noticeable with circular polarization.

Factors affecting satellite reception

The performance of a satellite TV receive only (TVRO) system is affected by a number of physical factors. Some of these are outlined below:

1. **The equivalent isotropic radiated power (EIRP) of the satellite..**
2. **The effective antenna diameter.**
3. **The low noise block (LNB) noise figure or noise temperature.**
4. **Coupling losses by waveguides and polarizers.**
5. **Antenna pointing losses: initial pointing error (degrees).**
6. **Antenna stability in wind or other environmental conditions (degrees).**
7. **Satellite station keeping accuracy.**
8. **Polarization losses.**
9. **Transponder ageing.**
10. **Rain attenuation for a signal availability (typically 99.5% of average year).**
11. **For Ku and Ka band, noise increase due to precipitation (rain, snow or hail).**
12. **Atmospheric absorption by oxygen and water vapour (depends on humidity).**
13. **Temperature variations.**
14. **The receiver (demodulator threshold) figure.**
15. **The signal modulation characteristics.**
16. **Scattering of signals due to blockages such as trees, buildings, birds and aircraft.**
17. **Spreading loss through the atmosphere.**

Transient effects such as passing birds and aircraft are largely unpredictable so can be neglected from the calculation. The others can all have a significant long-term effect, although factors 8, 9 and 10 can be neglected for S and C band reception.

Downlink path distance

The path distance, sometimes called the 'slant range', is the distance between the ground station and the satellite of interest. Clearly the further away from the equator this is, the longer the path distance. An equation used to calculate this is:
Path distance (D) = 6378.16 (m^2 + 1 -2m[cos(A) cos(B)])sq.root (km)

Wavelength

In many equations, including those that follow, a wavelength (λ) value rather than frequency is required for simplification. Conversion from frequency to wavelength can be done using:

$\lambda = c/f$

Where: c = the speed of light (2.998×10^8 m/s) f = frequency (Hz).

Free space loss

The free space loss (L_{FS}), or path loss, expresses the attenuation of microwave signals on their Earth-bound journey and occurs due to the spreading out of the beam. A good analogy is visualized by the intensity fall-off of a car headlight beam with distance. **The path loss increases with frequency and is greatest for low antenna elevation angles**. A suitable equation for calculating its value is:

$L_{FS} = 20 \log[(4000piD)/ \lambda]$ (dB)

Where: pi = 3.14159

D = path distance (km)

λ = wavelength (m).

Antenna gain

The antenna gain (Ga) increases with the effective antenna size which takes into account the efficiency (p) of the antenna. The gain can be expressed as:

Antenna gain (Ga) = $10 \log \{(pi.d)^2 p/100 \lambda^2\}$dB

Where d = the antenna diameter (m)

p = the percentage antenna efficiency (60-80% typically)

λ = wavelength (m)

Note: the antenna efficiency may be specified as a normalized value less than 1 (e.g. 0.67 or 0.80) rather than as a percentage. In such cases delete the term 100 in the denominator and substitute the normalized factor for p.

Effective antenna noise temperature

The effective antenna noise temperature (Ta) defined above is now discussed in a little more detail. The effective antenna noise temperature is determined by many factors, such as antenna size, elevation angle, external noise sources and atmospheric propagation effects During clear-sky conditions, the principal noise component of the effective antenna noise temperature is ground noise pick-up This is easy to see since, neglecting atmospheric propagation effects (rain, etc), this is virtually all the noise entering the antenna This is the 'antenna noise' parameter that manufacturers often tabulate for a range of elevation angles; it may also include a relatively small contribution by galactic background noise There are three main contributions to the overall antenna noise :

1. **Antenna noise temperature due to ground noise (Tant)** -The smaller the antenna, the wider and more spread out are the side lobes intersecting the warm earth, and, consequently, the more ground noise is picked up by the antenna. It can also be seen that these side lobes, principally the first side lobe, would intersect the ground at a higher elevation angle than that of a larger antenna and so would be a noisier device when set at a given elevation. Ground noise pick-up may be reduced, at the expense of gain, by under-illuminating the dish; thus, this factor essentially determines the efficiency of the dish. Size being equal, a prime

focus antenna would detect increased ground noise over an offset design since the head unit, directly mounted in the signal path, would be 'seen' at the same temperature as the Earth.

Since the antenna noise temperature has so many variable factors, it is apparent that in the absence of a manufacturer-supplied figure, an estimate is perhaps the best we can hope for. Equation takes into account the elevation and the diameter, may be used to calculate a reasonable approximation for the antenna noise under clear-sky conditions.

Tant = 15 + 30/D + 180/EL(K)

where: D = antenna diameter (m)

EL = dish elevation angle (degrees)

2. **Cosmic or galactic noise component**- This is background cosmic noise, principally the residual noise of the 'big bang'. It has a small noise temperature of about 2.7 K. This component is relatively small in relation to the error in estimating the ground noise component, and may be omitted from practical calculations. In any case, depending on how 'antenna noise' is defined in manufacturers' specifications, this may be incorporated.

3. **Atmospheric propagation components** -There are two main propagation effects experienced on the downlink. Firstly, atmospheric gaseous absorption by water vapour and oxygen; this is basically a clear-sky effect. Its value depends on the absolute humidity or vapour density measured in grams per square metre, the antenna elevation and the frequency involved. It is a relatively minor contributor below about 7.5 GHz. The second propagation effect is attenuation due to precipitation. Considering the uplink situation, a receiver on board a satellite will 'see' a fairly constant but high noise temperature emitted from the warm Earth of around 290 K, so further thermal energy emission by rain will have a negligible effect. In the downlink situation, the receiver is directed toward a relatively cool sky so, in a relative sense, the additional thermal noise contribution by rain is by no means a negligible component of the total system noise, especially if the receiver (LNB) is a low noise device operating in the Ku or Ka band. **The effects of rain and atmospheric absorption are negligible in the S and C bands.**

Precipitation will not only directly attenuate the signal (known as a 'rain fade'), but the system noise temperature will also increase since the temperature of the intervening medium approaches that of the Earth. It is important that the increase in system noise is taken into account and not just the attenuation experienced by a rain fade. The combination of the two is known as the "**downlink degradation (DND)**"

The effects of precipitation become significant above about 8 GHz. Rain, or to a lesser extent snow, fog, or cloud, attenuate and scatter microwave signals. The magnitude depends more on the size of the water droplets (in cubic wavelengths) rather than the precipitation rate itself. Heavier rain tends to comprise larger droplets so the two are normally related. As a general rule, the physical-medium temperature, of all forms of precipitation, is taken as 260 K. For clouds and clear-sky use 280 K.

PROCEDURE:

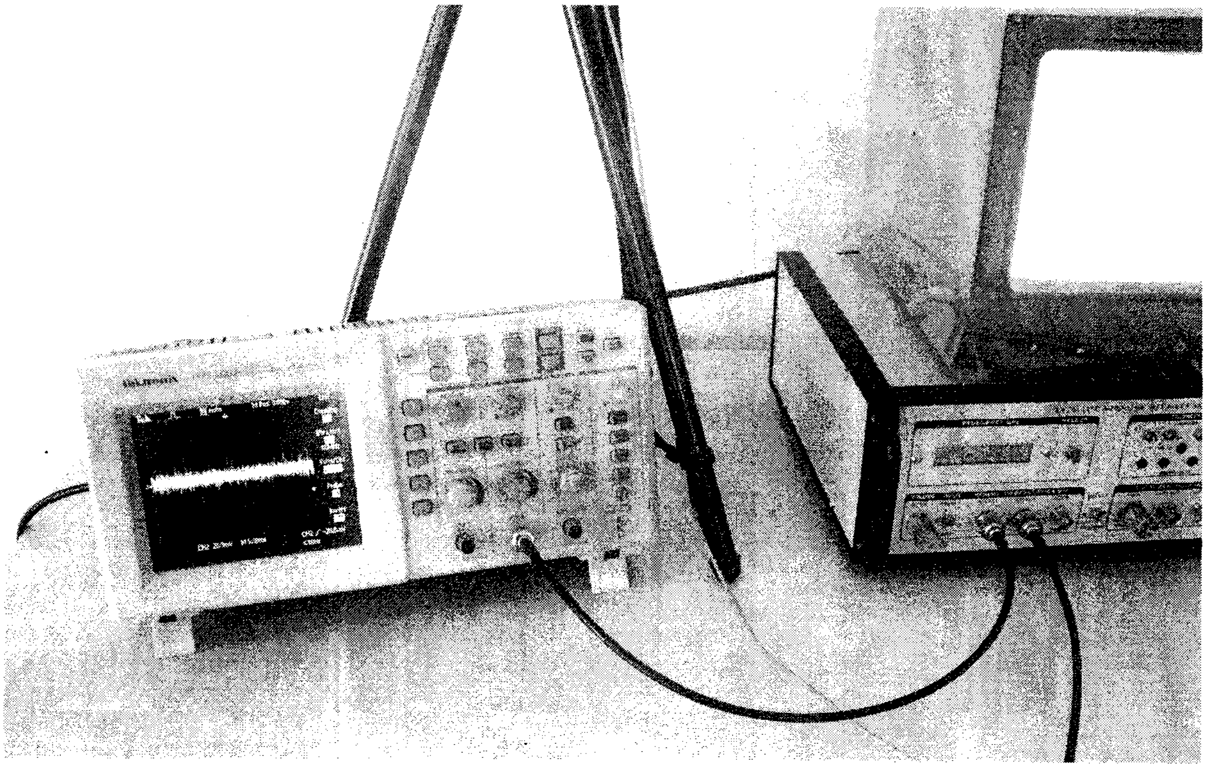
1. Setup the link as before. Press the frequency select switch of satellite emulator down link channel several times so as to set the frequency display from 2.400, 2.427, 2.454, 2.481 and then back to 2.400. This is done to ensure the emulator downlink PLL is locked and displayed frequency is generated correctly. If switching ON the 1kHz tone on transmitter will make the receiver sound to 1KHz test tone via satellite, PLL of complete link are O.K. and a successful sat link is said to be established.
2. Now, switch off the carrier by switching of both Transmitter (Tx) and satellite.
3. Receiver(Rx) will read only it's noise floor at RSSI output which has a DC voltage output in proportion to the received signal strength.
4. The chart at the back of the manual can be used to convert DC voltage to corresponding RF signal level in dBm or dBuV.
5. Say, in absence of any carrier Rx reads 0.92 V which is equal to -96 dBm (refer to chart).
6. Thus, -96 dBm is noise floor of Rx that means if carrier received by Rx is less than -96 dBm it will be unable to measure it.
7. Now, switch on Tx and satellite and say, the Rx reads 1.93 V which equals to -59 dBm of carrier level being received.
8. Thus, C/N = carrier level / noise level.As both noise and carrier signal detected are measured in dB, C/N can be calculated by taking the difference of two readings or C/N = carrier level(in dB) - noise level(in dB).
9. Hence, C/N = -59-(-96)=37 dB.
10. Make sure the Rx is not saturated with carrier otherwise incorrect C/N will be read. This can be done by increasing path loss at Rx and satellite and or taking Rx farther away from satellite.
11. Measure the C/N readings for different levels of pathloss.
12. Monitor the audio and video transmissions and correlate them to various levels of C/N. Does higher level of C/N result in better picture and sound quality.
13. If you are able to receive audio & video sent, clearly it means you are well above threshold level of signal. Now, the effect of noise can be seen if you decrease the received signal strength to a considerable level. This can be achieved by increasing the path loss.
14. This means the received signal is just above the noise floor of receiver. Although we are using FM demodulator but because the received signal is barely above the noise floor you can hardly receive any intelligent information. Thus, signal cannot be received below noise floor of Rx.

RESULT:

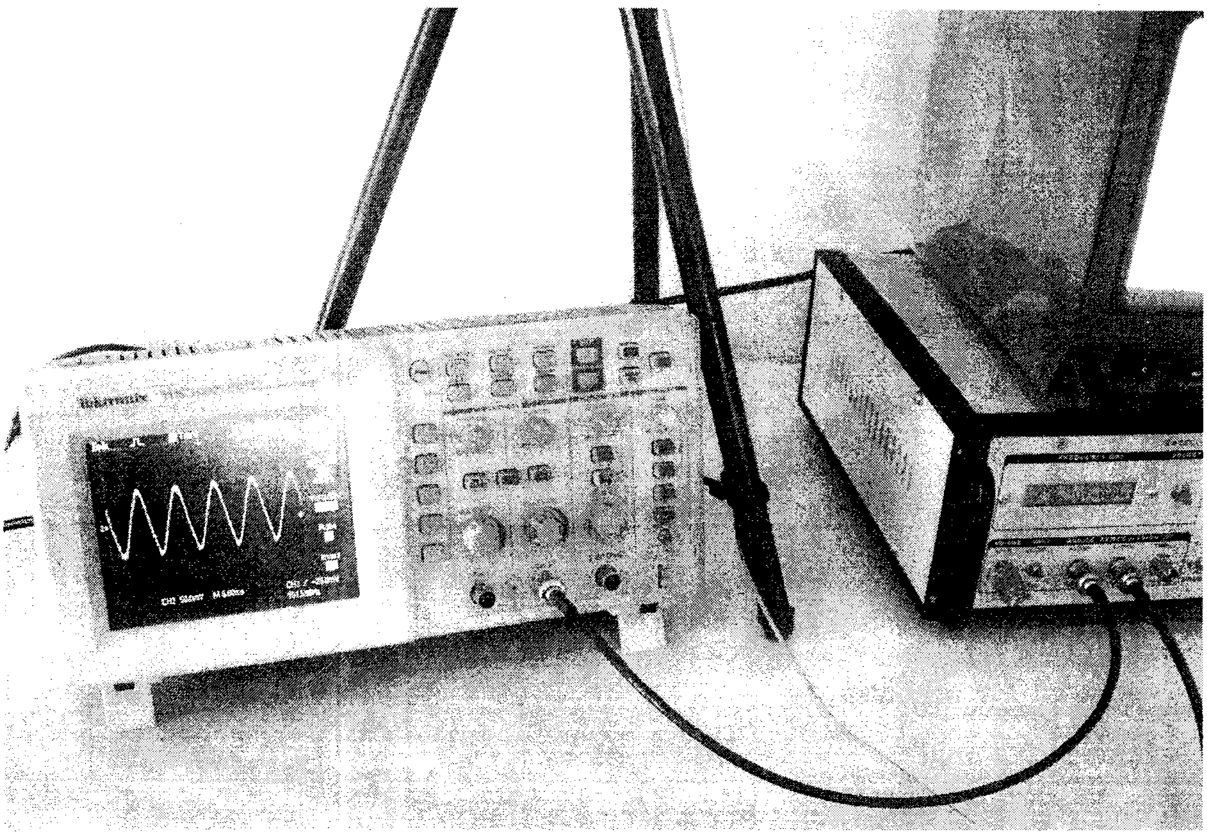
The difference between two readings of receiver noise level and carrier level is the C/N ratio in dB. Actual reading will depend on a number of factors and will differ from to case to case. Increasing the path loss and distance between antennas shall result in lower C/N ratios due to lower levels of received carrier. Amount of noise received/generated remains constant.

More power at transmitter shall result in better picture quality and more C/N ratio. Lower noise at receiver is essential for better picture. Higher gain antenna could be used to capture more signal. Hence a helix antenna could result in higher C/N.

Sparklies start appearing on black or white portions of picture when noise is increased. Further increasing the noise will make the picture lose it's sync resulting in complete loss of information.



Noise level(peak to peak) as read on CRO



Total signal level i.e, signal (peak to peak) + noise.

POWER CONVERSION TABLE

System: 50 Ω

dBm	mW	dBmV	mV(RMS)	mVp	mVpp	uV(RMS)	dBuV
-130	1.00E-13	-83.01	7.07E-05	1.00E-04	2.00E-04	7.07E-02	-23.01
-129	1.26E-13	-82.01	7.93E-05	1.12E-04	2.24E-04	7.93E-02	-22.01
-128	1.58E-13	-81.01	8.90E-05	1.26E-04	2.52E-04	8.90E-02	-21.01
-127	2.00E-13	-80.01	9.99E-05	1.41E-04	2.83E-04	9.99E-02	-20.01
-125	3.16E-13	-78.01	1.26E-04	1.78E-04	3.56E-04	1.26E-01	-18.01
-124	3.98E-13	-77.01	1.41E-04	2.00E-04	3.99E-04	1.41E-01	-17.01
-123	5.01E-13	-76.01	1.58E-04	2.24E-04	4.48E-04	1.58E-01	-16.01
-122	6.31E-13	-75.01	1.78E-04	2.51E-04	5.02E-04	1.78E-01	-15.01
-121	7.94E-13	-74.01	1.99E-04	2.82E-04	5.64E-04	1.99E-01	-14.01
-120	1.00E-12	-73.01	2.24E-04	3.16E-04	6.32E-04	2.24E-01	-13.01
-119	1.26E-12	-72.01	2.51E-04	3.55E-04	7.10E-04	2.51E-01	-12.01
-118	1.58E-12	-71.01	2.82E-04	3.98E-04	7.96E-04	2.82E-01	-11.01
-117	2.00E-12	-70.01	3.16E-04	4.47E-04	8.93E-04	3.16E-01	-10.01
-116	2.51E-12	-69.01	3.54E-04	5.01E-04	1.00E-03	3.54E-01	-9.01
-115	3.16E-12	-68.01	3.98E-04	5.62E-04	1.12E-03	3.98E-01	-8.01
-114	3.98E-12	-67.01	4.46E-04	6.31E-04	1.26E-03	4.46E-01	-7.01
-113	5.01E-12	-66.01	5.01E-04	7.08E-04	1.42E-03	5.01E-01	-6.01
-112	6.31E-12	-65.01	5.62E-04	7.94E-04	1.59E-03	5.62E-01	-5.01
-111	7.94E-12	-64.01	6.30E-04	8.91E-04	1.78E-03	6.30E-01	-4.01
-110	1.00E-11	-63.01	7.07E-04	1.00E-03	2.00E-03	7.07E-01	-3.01
-109	1.26E-11	-62.01	7.93E-04	1.12E-03	2.24E-03	7.93E-01	-2.01
-108	1.58E-11	-61.01	8.90E-04	1.26E-03	2.52E-03	8.90E-01	-1.01
-107	2.00E-11	-60.01	9.99E-04	1.41E-03	2.83E-03	9.99E-01	-0.01
-106	2.51E-11	-59.01	1.12E-03	1.58E-03	3.17E-03	1.12E+00	0.99
-105	3.16E-11	-58.01	1.26E-03	1.78E-03	3.56E-03	1.26E+00	1.99
-104	3.98E-11	-57.01	1.41E-03	2.00E-03	3.99E-03	1.41E+00	2.99
-103	5.01E-11	-56.01	1.58E-03	2.24E-03	4.48E-03	1.58E+00	3.99
-102	6.31E-11	-55.01	1.78E-03	2.51E-03	5.02E-03	1.78E+00	4.99
-101	7.94E-11	-54.01	1.99E-03	2.82E-03	5.64E-03	1.99E+00	5.99
-100	1.00E-10	-53.01	2.24E-03	3.16E-03	6.32E-03	2.24E+00	6.99
-99	1.26E-10	-52.01	2.51E-03	3.55E-03	7.10E-03	2.51E+00	7.99
-98	1.58E-10	-51.01	2.82E-03	3.98E-03	7.96E-03	2.82E+00	8.99
-97	2.00E-10	-50.01	3.16E-03	4.47E-03	8.93E-03	3.16E+00	9.99
-96	2.51E-10	-49.01	3.54E-03	5.01E-03	1.00E-02	3.54E+00	10.99
-95	3.16E-10	-48.01	3.98E-03	5.62E-03	1.12E-02	3.98E+00	11.99
-94	3.98E-10	-47.01	4.46E-03	6.31E-03	1.26E-02	4.46E+00	12.99
-93	5.01E-10	-46.01	5.01E-03	7.08E-03	1.42E-02	5.01E+00	13.99
-92	6.31E-10	-45.01	5.62E-03	7.94E-03	1.59E-02	5.62E+00	14.99
-91	7.94E-10	-44.01	6.30E-03	8.91E-03	1.78E-02	6.30E+00	15.99
-90	1.00E-09	-43.01	7.07E-03	1.00E-02	2.00E-02	7.07E+00	16.99
-89	1.26E-09	-42.01	7.93E-03	1.12E-02	2.24E-02	7.93E+00	17.99
-88	1.58E-09	-41.01	8.90E-03	1.26E-02	2.52E-02	8.90E+00	18.99
-87	2.00E-09	-40.01	9.99E-03	1.41E-02	2.83E-02	9.99E+00	19.99
-86	2.51E-09	-39.01	1.12E-02	1.58E-02	3.17E-02	1.12E+01	20.99
-85	3.16E-09	-38.01	1.26E-02	1.78E-02	3.56E-02	1.26E+01	21.99
-80	1.00E-08	-33.01	2.24E-02	3.16E-02	6.32E-02	2.24E+01	26.99
-79	1.26E-08	-32.01	2.51E-02	3.55E-02	7.10E-02	2.51E+01	27.99
-78	1.58E-08	-31.01	2.82E-02	3.98E-02	7.96E-02	2.82E+01	28.99
-77	2.00E-08	-30.01	3.16E-02	4.47E-02	8.93E-02	3.16E+01	29.99

dBm	mW	dBmV	mV(RMS)	mVp	mVpp	uV(RMS)	dBuV
-76	2.51E-08	-29.01	3.54E-02	5.01E-02	1.00E-01	3.54E+01	30.99
-75	3.16E-08	-28.01	3.98E-02	5.62E-02	1.12E-01	3.98E+01	31.99
-74	3.98E-08	-27.01	4.46E-02	6.31E-02	1.26E-01	4.46E+01	32.99
-73	5.01E-08	-26.01	5.01E-02	7.08E-02	1.42E-01	5.01E+01	33.99
-72	6.31E-08	-25.01	5.62E-02	7.94E-02	1.59E-01	5.62E+01	34.99
-71	7.94E-08	-24.01	6.30E-02	8.91E-02	1.78E-01	6.30E+01	35.99
-70	1.00E-07	-23.01	7.07E-02	1.00E-01	2.00E-01	7.07E+01	36.99
-69	1.26E-07	-22.01	7.93E-02	1.12E-01	2.24E-01	7.93E+01	37.99
-68	1.58E-07	-21.01	8.90E-02	1.26E-01	2.52E-01	8.90E+01	38.99
-67	2.00E-07	-20.01	9.99E-02	1.41E-01	2.83E-01	9.99E+01	39.99
-66	2.51E-07	-19.01	1.12E-01	1.58E-01	3.17E-01	1.12E+02	40.99
-65	3.16E-07	-18.01	1.26E-01	1.78E-01	3.56E-01	1.26E+02	41.99
-64	3.98E-07	-17.01	1.41E-01	2.00E-01	3.99E-01	1.41E+02	42.99
-63	5.01E-07	-16.01	1.58E-01	2.24E-01	4.48E-01	1.58E+02	43.99
-62	6.31E-07	-15.01	1.78E-01	2.51E-01	5.02E-01	1.78E+02	44.99
-61	7.94E-07	-14.01	1.99E-01	2.82E-01	5.64E-01	1.99E+02	45.99
-60	1.00E-06	-13.01	2.24E-01	3.16E-01	6.32E-01	2.24E+02	46.99
-59	1.26E-06	-12.01	2.51E-01	3.55E-01	7.10E-01	2.51E+02	47.99
-58	1.58E-06	-11.01	2.82E-01	3.98E-01	7.96E-01	2.82E+02	48.99
-57	2.00E-06	-10.01	3.16E-01	4.47E-01	8.93E-01	3.16E+02	49.99
-56	2.51E-06	-9.01	3.54E-01	5.01E-01	1.00E+00	3.54E+02	50.99
-55	3.16E-06	-8.01	3.98E-01	5.62E-01	1.12E+00	3.98E+02	51.99
-54	3.98E-06	-7.01	4.46E-01	6.31E-01	1.26E+00	4.46E+02	52.99
-53	5.01E-06	-6.01	5.01E-01	7.08E-01	1.42E+00	5.01E+02	53.99
-52	6.31E-06	-5.01	5.62E-01	7.94E-01	1.59E+00	5.62E+02	54.99
-51	7.94E-06	-4.01	6.30E-01	8.91E-01	1.78E+00	6.30E+02	55.99
-50	1.00E-05	-3.01	7.07E-01	1.00E+00	2.00E+00	7.07E+02	56.99
-49	1.26E-05	-2.01	7.93E-01	1.12E+00	2.24E+00	7.93E+02	57.99
-48	1.58E-05	-1.01	8.90E-01	1.26E+00	2.52E+00	8.90E+02	58.99
-47	2.00E-05	-0.01	9.99E-01	1.41E+00	2.83E+00	9.99E+02	59.99
-46	2.51E-05	0.99	1.12E+00	1.58E+00	3.17E+00	1.12E+03	60.99
-45	3.16E-05	1.99	1.26	1.78	3.56	1.26E+03	61.99
-44	3.98E-05	2.99	1.41E+00	2.00E+00	3.99E+00	1.41E+03	62.99
-43	5.01E-05	3.99	1.58E+00	2.24E+00	4.48E+00	1.58E+03	63.99
-42	6.31E-05	4.99	1.78E+00	2.51E+00	5.02E+00	1.78E+03	64.99
-41	7.94E-05	5.99	1.99E+00	2.82E+00	5.64E+00	1.99E+03	65.99
-40	1.00E-04	6.99	2.24	3.16	6.32	2.24E+03	66.99
-39	1.26E-04	7.99	2.51E+00	3.55E+00	7.10E+00	2.51E+03	67.99
-38	1.58E-04	8.99	2.82E+00	3.98E+00	7.96E+00	2.82E+03	68.99
-37	2.00E-04	9.99	3.16E+00	4.47E+00	8.93E+00	3.16E+03	69.99
-36	2.51E-04	10.99	3.54E+00	5.01E+00	1.00E+01	3.54E+03	70.99
-35	3.16E-04	11.99	3.98	5.62	11.25	3.98E+03	71.99
-34	3.98E-04	12.99	4.46E+00	6.31E+00	1.26E+01	4.46E+03	72.99
-33	5.01E-04	13.99	5.01E+00	7.08E+00	1.42E+01	5.01E+03	73.99
-32	6.31E-04	14.99	5.62E+00	7.94E+00	1.59E+01	5.62E+03	74.99
-31	7.94E-04	15.99	6.30E+00	8.91E+00	1.78E+01	6.30E+03	75.99
-30	1.00E-03	16.99	7.07	10.00	20.00	7.07E+03	76.99
-29	1.26E-03	17.99	7.93E+00	1.12E+01	2.24E+01	7.93E+03	77.99
-28	1.58E-03	18.99	8.90E+00	1.26E+01	2.52E+01	8.90E+03	78.99
-27	2.00E-03	19.99	9.99E+00	1.41E+01	2.83E+01	9.99E+03	79.99
-26	2.51E-03	20.99	1.12E+01	1.58E+01	3.17E+01	1.12E+04	80.99
-25	3.16E-03	21.99	12.57	17.78	35.57	1.26E+04	81.99

-24	3.98E-03	22.99	1.41E+01	2.00E+01	3.99E+01	1.41E+04	82.99
dBm	**mW**	**dBmV**	**mV(RMS)**	**mVp**	**mVpp**	**uV(RMS)**	**dBuV**
-23	5.01E-03	23.99	1.58E+01	2.24E+01	4.48E+01	1.58E+04	83.99
-22	6.31E-03	24.99	1.78E+01	2.51E+01	5.02E+01	1.78E+04	84.99
-21	7.94E-03	25.99	1.99E+01	2.82E+01	5.64E+01	1.99E+04	85.99
-20	0.01	26.99	22.36	31.62	63.25	2.24E+04	86.99
-19	1.26E-02	27.99	2.51E+01	3.55E+01	7.10E+01	2.51E+04	87.99
-18	1.58E-02	28.99	2.82E+01	3.98E+01	7.96E+01	2.82E+04	88.99
-17	2.00E-02	29.99	3.16E+01	4.47E+01	8.93E+01	3.16E+04	89.99
-16	2.51E-02	30.99	3.54E+01	5.01E+01	1.00E+02	3.54E+04	90.99
-15	0.03	31.99	39.76	56.23	112.47	3.98E+04	91.99
-14	3.98E-02	32.99	4.46E+01	6.31E+01	1.26E+02	4.46E+04	92.99
-13	5.01E-02	33.99	5.01E+01	7.08E+01	1.42E+02	5.01E+04	93.99
-12	6.31E-02	34.99	5.62E+01	7.94E+01	1.59E+02	5.62E+04	94.99
-11	7.94E-02	35.99	6.30E+01	8.91E+01	1.78E+02	6.30E+04	95.99
-10	0.10	36.99	70.71	100.00	200.00	7.07E+04	96.99
-9	1.26E-01	37.99	7.93E+01	1.12E+02	2.24E+02	7.93E+04	97.99
-8	1.58E-01	38.99	8.90E+01	1.26E+02	2.52E+02	8.90E+04	98.99
-7	2.00E-01	39.99	9.99E+01	1.41E+02	2.83E+02	9.99E+04	99.99
-6	2.51E-01	40.99	1.12E+02	1.58E+02	3.17E+02	1.12E+05	100.99
-5	0.32	41.99	125.74	177.83	355.66	1.26E+05	101.99
-4	3.98E-01	42.99	1.41E+02	2.00E+02	3.99E+02	1.41E+05	102.99
-3	5.01E-01	43.99	1.58E+02	2.24E+02	4.48E+02	1.58E+05	103.99
-2	6.31E-01	44.99	1.78E+02	2.51E+02	5.02E+02	1.78E+05	104.99
-1	7.94E-01	45.99	1.99E+02	2.82E+02	5.64E+02	1.99E+05	105.99
0	1.00	46.99	223.61	316.23	632.46	2.24E+05	106.99
1	1.26	47.99	250.89	354.81	709.63	2.51E+05	107.99
2	1.58	48.99	281.50	398.11	796.21	2.82E+05	108.99
3	2.00	49.99	315.85	446.68	893.37	3.16E+05	109.99
4	2.51	50.99	354.39	501.19	1002.37	3.54E+05	110.99
5	3.16	51.99	397.64	562.34	1124.68	3.98E+05	111.99
6	3.98	52.99	446.15	630.96	1261.91	4.46E+05	112.99
7	5.01	53.99	500.59	707.95	1415.89	5.01E+05	113.99
8	6.31	54.99	561.67	794.33	1588.66	5.62E+05	114.99
9	7.94	55.99	630.21	891.25	1782.50	6.30E+05	115.99
10	10.00	56.99	707.11	1000.00	2000.00	7.07E+05	116.99
11	12.59	57.99	793.39	1122.02	2244.04	7.93E+05	117.99
12	15.85	58.99	890.19	1258.93	2517.85	8.90E+05	118.99
13	19.95	59.99	998.81	1412.54	2825.08	9.99E+05	119.99
14	25.12	60.99	1120.69	1584.89	3169.79	1.12E+06	120.99
15	31.62	61.99	1257.43	1778.28	3556.56	1.26E+06	121.99
16	39.81	62.99	1410.86	1995.26	3990.52	1.41E+06	122.99
17	50.12	63.99	1583.01	2238.72	4477.44	1.58E+06	123.99
18	63.10	64.99	1776.17	2511.89	5023.77	1.78E+06	124.99
19	79.43	65.99	1992.90	2818.38	5636.77	1.99E+06	125.99
20	100.00	66.99	2236.07	3162.28	6324.56	2.24E+06	126.99
21	125.89	67.99	2508.91	3548.13	7096.27	2.51E+06	127.99
22	158.49	68.99	2815.04	3981.07	7962.14	2.82E+06	128.99
23	199.53	69.99	3158.53	4466.84	8933.67	3.16E+06	129.99
24	251.19	70.99	3543.93	5011.87	10023.74	3.54E+06	130.99
25	316.23	71.99	3976.35	5623.41	11246.83	3.98E+06	131.99
26	398.11	72.99	4461.54	6309.57	12619.15	4.46E+06	132.99
27	501.19	73.99	5005.93	7079.46	14158.92	5.01E+06	133.99

28	630.96	74.99	5616.75	7943.28	15886.56	5.62E+06	134.99
29	794.33	75.99	6302.10	8912.51	17825.02	6.30E+06	135.99
dBm	**mW**	**dBmV**	**mV(RMS)**	**mVp**	**mVpp**	**uV(RMS)**	**dBuV**
30	1000.00	76.99	7071.07	10000.00	20000.00	7.07E+06	136.99

Units:

E or V = Volts (can use either, as per convention standards)
R = Ohms (impedence/resitance)
P = Power (Watts, dBm, mW, or W)
dB = decibel ratio ($\log_{10}$) - all log's will be to base 10
W = Watts = (E.E)/R
u = micro = 10E-6 (for all units - E, R, P, or V)
m = milli = 10E-3 (for all units - E, R, P, or V)
dBm = decibel ratio of Watts W to one milliwatt
= $10\log_{10}$ (W/mW)
dBuV = decibel ratio of Volts to one microvolt
= $20\log_{10}$ {V/uV} or, for example, {E/uV}

<u>Conversions for 50 ohm systems:</u>

1. To convert dBm to dBuV add 107 dB: dBuV = dBm + 107 dB
2. To conver dBuV to dBm subtract 107 dB: dBm = dBuV - 107 dB

Proof:

Remember, 0 dBm = 1 mW (milliwatt) = 0.001 Watts

E = Square Root of (W x R) - assume R = 50 Ohms
Note: for dBm our reference will be 1 mW
E = Square Root (1mW* x 50 ohms) = 0.224 Volts
dBuV = 20 $\log_{10}$ (0.224 Volts/1uV*) = 107 dBuV
Therefore, 107 dBuV = 0 dBm in a 50 W system
Using this as the scale factor: dBm + 107 dB = dBuV
* Must be entered in Watts (0.001 or 1x10-3 W = 1 mW)
* Must be entered in Volts (0.000001 or 1x10E-6 V = 1uV)

POWER – RSSI (SAT Rx) CONVERSION TABLE (Approximate Values only)

dBm	pW	RSSI (V)
-96	0.251	0.92
-95	0.361	0.93
-94	0.39	0.93
-93	0.50	0.93
-92	0.63	0.94
-91	0.79	0.95
-90	1.00	0.97
-89	1.26	0.99
-88	1.58	1.01
-87	1.99	1.03
-86	2.51	1.06
-85	3.16	1.08
-84	3.98	1.1
-83	5.01	1.13
-82	6.31	1.16
-81	7.9	1.18
-80	10.0	1.21
-79	12.6	1.24
-78	15.8	1.27
-77	19.9	1.30
-76	25.1	1.33
-75	31.6	1.37
-74	39.8	1.40
-73	50.1	1.43
-72	63.1	1.46
-71	79.0	1.51
-70	100	1.54
-69	126	1.58
-68	158	1.62
-67	199	1.65

-66	251	1.69
-65	316	1.73
-64	398	1.76
-63	501	1.80
-62	631	1.83
-61	790	1.87
-60	1000	1.90
-59	1260	1.93
-58	1580	1.97
-57	1980	2.01
-56	2510	2.51
dBm	**nW**	**RSSI (V)**
-55	3.16	3.06
-54	3.98	3.34
-53	5.01	3.49
-52	6.31	3.58
-51	7.9	3.63
-50	10.0	3.67
-49	12.6	3.70
-48	15.8	3.72
-47	19.9	3.74
-46	25.1	3.75
-45	31.6	3.77
-44	39.8	3.78
-43	50.1	3.80
-42	63	3.80
-41	79	3.81
-40	100	3.82
-39	126	3.83
-38	158	3.84
-37	198	3.86
-36	251	3.88
-35	316	3.92

-34	398	4.00
-33	501	4.06
-32	631	4.1
-31	790	4.13
-30	1000	4.14
-29	1260	4.17
-28	1580	4.18
-27	1990	4.20
-26	2510	4.21
-25	3160	4.22
-24	3980	4.22
-23	5010	4.23
-22	6340	4.24
-21	7940	4.25
-20	10,000	4.25

These are approximate Values only.