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Satellite Communications Systems are infrastructures that can be used for broadband multimedia applications. In the communication satellite field, the C-band (4-6 GHz) frequencies have been used since the beginning and are now saturated. The Ku-band (11-18 GHz) has been used also for communication satellite systems, because with this frequency a bigger bandwidth can be applied. The Ku-band has other advantages, such as avoidance of interference with terrestrial microwave systems that often use the C-band frequency. However, for Indonesia, the use of the Ku-band needs a thorough examination because frequencies above 10 GHz are vulnerable to rain, especially heavy rain that often occurs in Indonesia. This article examines the possibility of using the Ku-band for satellite communication systems in Indonesia.

In 1976 President Soeharto of the Republic of Indonesia, gave the name PALAPA to the first Indonesian satellite. At that time Indonesia was the 3rd nation in the world to use satellites as its telecommunications infrastructure. Indonesia can be proud of this fact, because Indonesia's neighbors Singapore, Malaysia, the Philippines and Thailand had not yet shown any interest in having their own satellites.

Indeed, considering Indonesia's geographical features: consisting of islands stretching from West to East and from South to North, it is reasonable for Indonesia to adopt a satellite platform for its communications system. By using satellites one can obtain wide coverage, quick rollout of facilities (compared to buried optic fiber cables) unconstrained by natural conditions and distance.

Indonesia is now not alone in South-east Asia/East Asia in utilizing satellite services for voice, video and data. Twenty years after the historic launch of its first satellite in 1976, Malaysia and Thailand have launched their own satellites, followed by Singapore and Taiwan constructing their satellite cooperatively. In addition are Hongkong, Korea (Koreasat) and Japan (JCSAT). The frequency bands used for satellite communications have also developed. Besides using the C-band, the use of the Ku-band has become more and more popular, even though Indonesian satellite operators are still unsure about the technical feasibility of using the Ku-band in Indonesia.

Breakthroughs in the satellite field should allow Indonesiato use frequencies higher than 10 GHz, i.e. the Ku-band (11 - 18 GHz) and Ka-band (20 - 30 GHz). The advantage is that the higher the frequency used, the larger the bandwidth. The limitation is that frequencies higher than 10 GHz are subject to higher rain attenuation, thereby causing a decrease in communication "availability."

The International Telecommunication Union, ITU, has categorized Indonesia as Region P, countries with very high rain precipitation. According to ITU's version, rain intensity that will cause the interruption of a communication link for 0.01% per year is 145 mm/hour. Such rain intensity can cause 28 db rain attenuation for a link working in the 14 GHz band; that is pretty high. Such an attenuation should be compensated for with powerful RF equipment at the transmit side. The value can be calculated by using link-budget analysis.

Should we be pessimistic that we cannot use such frequencies? Let us study it carefully. We should ask ourselves whether it will rain all year long. Of course not. And will the rain attenuation be 28 db consistently? This is also not the case, because the rain attenuation is dependent on the rainfall at a certain location. There is still hope for the use of frequencies above 10 GHz in Indonesia.

Rainfall Rate

The Rainfall Rate is one of the factors used to determine the degree of rain attenuation in the propagation of wireless communications, including satellite communications. Field measurements and recordings for long time periods are the best (empirical) method to know the rainfall rate in a country. Such data can then be used for various calculations concerning signal attenuation caused by rain.

Another way is to depend on models that have been developed by such bodies as the ITU-R Rep. 563-4 and the Global Crane model. Although both models are used to calculate rain attenuation in Indonesia, some experts consider these models not accurate enough, because there were too few samples used when developing the models.

Indonesia is fortunate that further research has been done on this matter with the idea that more accurate models can be constructed. This research has been carried out at 9 locations in the Indonesian archipelago: Jatiluhur, Cibinong, Denpasar, Padang, Surabaya, Bandung, Tanahmerah, Putusibau and Maros. Also one location is in Singapore, i.e. Bukit Timah, which is geographically located in the same position as Indonesia.

Results show that the Rainfall Rate for a 0.01% (R0.01) observation time is as follows (see table).

Location	Measurements Results	ITU-R Rep.563-4	Global Crane
Jatiluhur	109.2 mm/h	145 mm/h	147 mm/h
Surabaya	119.6 mm/h	145 mm/h	147 mm/h
Bandung	120 mm/h	145 mm/h	147 mm/h

Singapura	125.5 mm/h	145 mm/h	147 mm/h
Denpasar	109 mm/h	145 mm/h	147 mm/h
Tanahmerah	138 mm/h	145 mm/h	147 mm/h
Cibinong	159 mm/h	145 mm/h	147 mm/h
Maros	148 mm/h	145 mm/h	147 mm/h
Putussibau	152 mm/h	145 mm/h	147 mm/h
Padang	146 mm/h	145 mm/h	147 mm/h

Table 1.1. R0.01 Rainfall Rate Measurements in Indonesia

Note: Besides the ITU- and Global Crane model, there exist also the Rice-Holmberg and ESA/ Salonen Baptista models.

From the table can be seen that there are significant differences between the results of the field measurements and the calculations using several well-known models.

Rainfall Rate Prediction Model for Indonesia

The Rainfall Rate Prediction Model applicable especially for Indonesia can be developed more accurate and convincingly with the availability of field measurements as presented above. By using abovementioned data, and added to it (other) data concerning rain and thunderstorm days from the Indonesian Meteorological and Geophysical Institute, the Rainfall Rate Prediction Model for the Indonesia archipelago becomes:

- R0.01 = f(Lat,Long,M,Mm) = 128.192 - 0.037Lat - 0.393Long + 0.012M + 0.017Mm
- R0.01 = rainfall-rate 0.01 percent of time in a year (mm/h)
- M = average rainfall a year (mm)
- Mm = maximum rainfall (monthly) in 30 years
- Lat = latitude
- Long = longitude

This model should be used when carrying out wireless communication link planning for wireless local loops, line of sight and satellite.

Rain Attenuation Prediction Model

The rain attenuation for wireless communication links can be calculated using following models:

- ITU - R (formerly CCIR Model)
- SAM (Simple Attenuation Model)
- Global Crane Model
- Model DAH (Dissanayake, Allnutt, Haidara Model)

To confirm which model is the prefered model to be used in Indonesia, field measurements should also be carried out. Measurements of rain attenuation in Indonesia have been done for satellite communication links in Padang, Cibinong, Surabaya and Bandung. It has been found out, after due analysis, that the DAH Model for rain attenuation prediction is valid for Indonesia, besides the ITU Model. The DAH Model has become an ITU Recommendation since 2001 (Recommendation No. ITU-R P.618-7).

Based on calculations using the Rainfall Rate Prediction Model for Indonesia, the rainfall rate can be found for several locations in Indonesia. The values of the rainfall rate are then used for calculating the Rain Attenuation using the DAH Model. Thus can be calculated the "link availability" predictions for Ku-band systems in Indonesia. The calculations by the author of this article show that the use of the Ku-band for satellite communications systems is feasible with a link availability of 99.7%.

As a practical experience, based on field test results for 512 kbps data rate using a 1.8 m diameter antenna, 4 watts RF power and distance between transmitter and receiver of 180 km, demonstrated a link availability of 99.9%, confirming our previous calculations.

The Use of Ku-band in Tropical Regions

The use of the Ku-band for satellite communications in tropical regions like Indonesia seems to become more frequent. We observe that several satellites "parked" above Indonesia have Ku-band transponders, and even Ka-band transponders. Just look at the satellite owned by NewSkies (NSS 6), launched in December 2002 and positioned at 95° East, containing only Ku-band transponders and with a footprint directed to Indonesia (Sumatra, Java, Borneo, Celebes, Bali, Nusa Tenggara, Moluccas). This is also the case for the iPSTAR satellite, to be launched this year, 2004. The Malaysia owned Measat 3, to be launched in 2005 and co-located with the Measat 1 satellite will have 24 Ku-band transponders. The Ku-band footprint directed towards Indonesia has been named by Measat the "Ku-band for Indonesia". Measat 4 is planned to cover the whole of Indonesia from West to East. This satellite will be launched by Malaysia in the year 2007.

Why have those satellite planners the courage to use the Ku-band frequency? Of course they have calculated the technical feasibility, besides applying a regenerative system, also called Automatic Link Control, which is to exercise control over the power of the satellite to compensate for rain attenuation up to 10 db. Furthermore, for the ground segment there now exists a new development, that is the use of AUPC (automatic uplink power control) and Turbo Coding. Actually, AUPC has long been available, but it is only recently being mass-produced. With AUPC we can automatically control the transmit power in line with the rain attenuation, in general up to 9 db. With turbo coding, we can also save the power used, so that with the same transmit power we will obtain a bigger fade margin compared to a satellite modem that does not use turbo coding. At this moment, Adaptive Coding is being developed whereby the system will adapt itself to the weather conditions. The system will change the modulation in case of a weather change (rain), while retaining the bandwidth; only the throughput will decrease. By using adaptive coding, link-availability will increase.

There is an additional problem in satellite communications. TCP/IP applications have difficulties in passing through because of the long delay caused by the time it takes for the signal to travel from earth to space to earth. TCP/IP was designed for short delay times, passing through terrestrial connections. Are there solutions for this? There are, among others, by re-engineering the TCP algorithm, TCP spoofing and IP over DVB. Besides that, there is a TCP that has been designed for satellites (see http://www.idirect.net/). This problem is not a serious hindrance any more. VPN services over satellites are no longer just a dream; it has been proven that they can be applied successfully.

It can be imagined what could happen if these various new technologies are combined. It is time that Indonesia abandons its wariness to use Ku-band frequencies. An inexpensive system of broadband satellite services will assist greatly in the process of empowering its citizens, because for such a wide area as Indonesia, the appropriate information technology infrastructure is satellites. One can imagine ATMs that respond quickly, and also Internet kiosks that can be moved from one site to another. The penetration of banking services can be executed faster, as well as the penetration of Internet. Distance learning and e-learning can be established relatively speedily and at lower cost. There is even the possibility to have General Elections on-line with VSATs connected to every community. This agility can only be carried out if the equipment used robust, fast and compact. We can do this with Ku-band systems.

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