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Effect of depolarization on dual-polarized satellite link with 16- and 32-ary modulation schemes

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1. Background and Purpose

At present, the needs of satellite broadcasting are extending. Since we must meet the needs, we want to enrich the quality of satellite broadcasting. And the transmission quantity should increase, so the technology of high capacity transmission needs more progress. On the other hand, the information transmission using a radio wave is progressing too except the field of the satellite broadcasting. Also we should consider the effective utilization of a frequency spectrum. Then, we want to use a more high frequency band that is uncultivated. Because of this situation, 21GHz-band and 42GHz-band were assigned internationally as future frequency bands for satellite broadcasting. These are shown in Table.1. Regarding the increasing transmission quantity, we should remark "dual polarized satellite broadcasting system" and "multi-level modulation method". If we can use the technology effectively at the same time, the transmission quantity becomes several times as much. And if these can be applied on those bands, rapidly increasing of this quantity can be realized. But we will have some demerits too. For example, those are large rain attenuation, noise, and cross polarization interference. They degrade link characteristics. Then purpose of this research is assessing effect of these factors quantitatively.

2. Technology of Increasing Transmission Quantity and Factors Degrading Link Characteristics

2.1 Multi-level modulation scheme

BER degradation due to dual-polarization in case of QPSK is discussed in reference [1]. We treat 4 modulation methods in this research. Those 4 methods are 16QAM, 32QAM, 16APSK, and 32APSK. Fig.1 shows these constellations.

2.2 Dual-polarized Satellite broadcasting system

Dual-polarized system shares two orthogonal polarizations, and each polarization has different information from each other. In this way, this system enables to multiply transmission quantity. Theoretically, two polarizations are not interference because these are orthogonal. But on transmission path, some medium can break that orthogonality and this can lead degradation of link characteristic. The extent of this degradation is shown by XPD as follows:

$$XPD_H = -20\log|h/H| \text{ [dB]}$$

when H is received field strength of horizontal polarization in using horizontal polarization for transmission, and h is field strength of vertical component generated due to disordered horizontal polarization.

2.3 Link characteristic degradation

Main factors degrading link characteristic are rain attenuation, cross polarization interference, and noise. These can cause errors in receiving phase and amplitude of radio wave, and information cannot be transmitted correctly.

3. Assessing link characteristics by MATLAB & SIMULINK(R2009a)

3.1 Optimization of APSK constellation

In applying four modulation schemes mentioned above, we want to assess link characteristics. Firstly APSK constellations need to be optimized because those have infinite patterns.

3.2 BER cumulative distribution

Bit error rate (BER) cumulative distribution is needed to assess link characteristics. To derive this, we need 'cumulative distribution of rain attenuation', 'relation between rain attenuation and XPD', and 'BER characteristics with regards to each modulation schemes' shown from Fig.2 to 4. In this research, we considered Tokyo's rain attenuation statistics, and assume circular polarization.

4. Result and Discussion

4.1 Optimization of APSK constellation

Result is shown in Table.2. And Fig.4 shows BER characteristics with regards to each modulation scheme when results shown in Table.2 are applied to 16APSK and 32APSK.

4.2 BER cumulative distribution

Fig.5 and 6 show BER cumulative distribution of 32APSK in which BER characteristics are the worst among 4 modulation schemes. σ_0 is a standard deviation of an axis of symmetry of a raindrop on transmission path, and 0° is virtual and worst term.

4.3 Discussion

We derive BER ratio of dual-polarization case to single polarization one, and assess the extent of degradation in using 'dual-polarized satellite broadcasting system'. Regarding 21GHz-band, Fig.7 shows this ratio. This ratio becomes about 4 when value of BER is 10^{-3} and cumulative probability is 0.1%. So BER with dual polarization in 21GHz-band is about 4×10^{-3} in this case. Regarding 42GHz-band, we can also derive similarly. And in 42GHz-band, dual-polarization's curve and single-polarization's one are very similar, so we can say the effect of dual-polarization is very small in 42GHz-band.

As shown in each BER characteristics, degradation of BER by degradation of C/N is remarkable, and rain attenuation causes that degradation in C/N. If availability that should be achieved is 99%, rain attenuation is about 3dB when cumulative probability is 1%. In any modulation schemes, if we subtract 3dB as rain attenuation from C/N required to achieve BER 10^{-4}, BER is degraded to about 3×10^{-3}. In other words, the degradation of BER is more than 10 times. Therefore a main cause of degradation of BER is rain attenuation rather than depolarization in these modulation schemes.

5. Conclusion and Future Research

Regarding multi-level modulation scheme, especially APSK constellation, we could optimize that, and we showed quantitatively it is enough with regards to only amplitude adjustment. In the near future, advanced technology will realize applying that. Regarding dual-polarization, we showed the effect of dual polarization on BER degradation is small in 21GHz-band and 42GHz-band. Cross polarization interference will not be critical cause of degradation. On the other hand, the most critical cause of degradation is rain attenuation.

In present actual satellite broadcasting, satellite repeater have non-linear amplifier. But in this research, it is not considered. After this, in order to do more realistic simulation, non-linear amplifier must be reflected in a block diagram of this simulation.

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Table.1 Future frequency bands for BSS

future frequency band
21.4-22.0 GHz
40.5-41.0 GHz
41.0-42.5 GHz

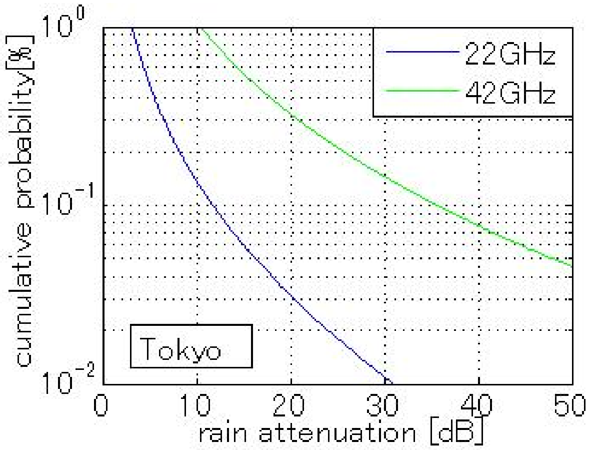

Fig.2 Cumulative distribution of rain attenuation at Tokyo

Table.2 Optimized APSK constellations

Modulation scheme	**16APSK**	**32APSK**
Amplitude 16APSK's inner circle 32APSK's center circle	**0.4**	**0.7**
Phase difference	**0°**	**15°**

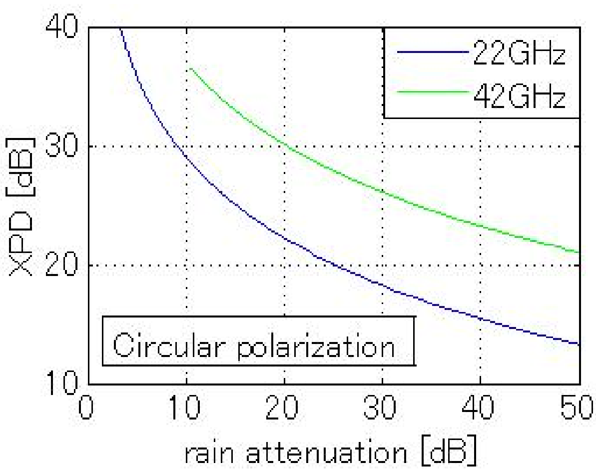

Fig.3 Relation between rain attenuation and XPD

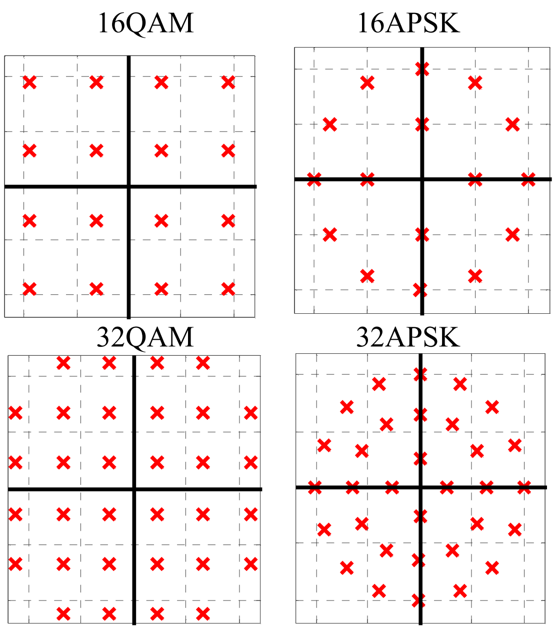

Fig.1 Constellations of modulation schemes

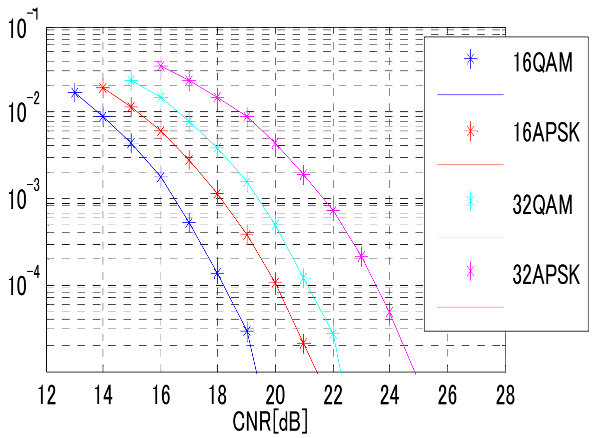

Fig.4 BER characteristics of each modulation schemes

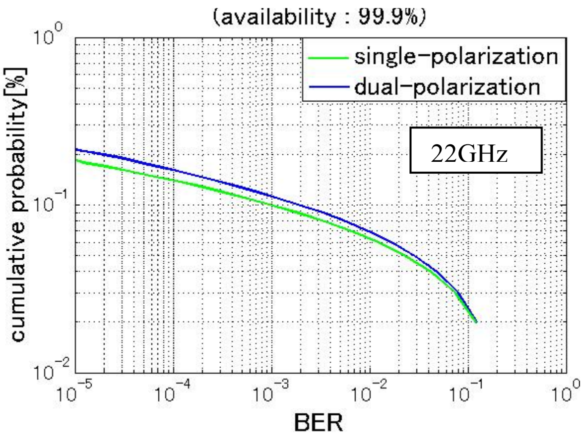

Fig.5 BER cumulative distribution of 32APSK

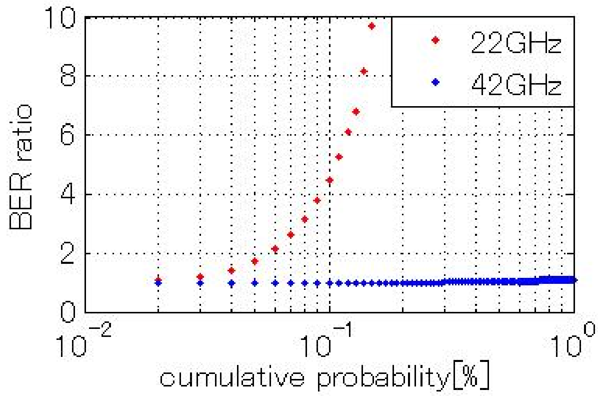

Fig.7 BER ratio of 32APSK

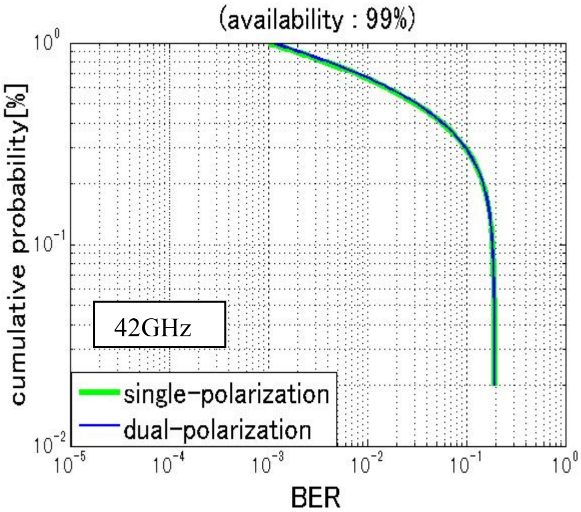

Fig.6 BER cumulative distribution of 32APSK

References

[1] H. Ohta and H. Fukuchi, "Effect of rain- and ice-induced depolarisation on cual polarised 21GHz-band digital satellite broadcasting system", Elect. Lett., vol.34, no.4, pp. 330-332, 1998.

[2] H. Fukuchi, "Relationship between rain attenuation and depolarization up to 100GHz", Int. Symp. Ant. And Prop.(ISAP2008), Taipei, Oct. 2008.